OPERATING AND MAINTENANCE MANUAL

RESOLVER/SYNCHRO SIMULATOR

MODEL 530

NAI TM 5005

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STATUS OF CHANGE PAGES

Following is a list of all pages in this manual, their change status and the date of change. A zero (0) in the Change Status column indicates an original issue. Changed text is indicated by a vertical bar in the margin. Changed illustrations are indicated by a vertical bar next to the title.

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6-1 thru 6-10. . . .	0
7-1 thru 7-10. . . .	0
8-1 thru 8-3	0

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

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SECTION 1

GENERAL DESCRIPTION

1.1 GENERAL

This manual contains general description, installation, operating instructions, maintenance and troubleshooting procedures, replacement parts lists, and schematic diagrams for the Resolver-Synchro Simulator, Model 530 (herein after referred to as the Model 530).

1.2 PHYSICAL DESCRIPTION

The Model 530 (fig. 1-1) is a 3-1/2-inch rack mounted unit.

1.3 FUNCTIONAL DESCRIPTION

The Model 530 is a dual-mode resolver-synchro simulator. It generates electrical data of angular shaft position of either three-wire synchros or four-wire resolvers to an accuracy of 2 seconds of arc.*

The unit meets all requirements for use in providing ideal inputs for testing of synchro and resolver receivers, or systems under test or evaluation which operate from synchro or resolver signals. In addition to its dual-mode capabilities, the unit provides switch selected line-to-line voltages of 11.8, 26, 90, or 115 volts, from either 26 V or 115 V input excitation. Consequently, the unit may be used for testing any standard synchros or resolvers, as well as systems utilizing these components. A complete description of its use in testing resolvers and synchros of various types is covered in Section 7.

The Model 530 is designed to provide full accuracy at any frequency from 400 to 800 Hz, and may be used up to 10 kHz with reduced accuracy. Specified accuracy is maintained for all angles over the complete range of readout. Similarly, loading errors which might arise from output impedance unbalance are minimized due to a high degree of impedance match coupled with a low output impedance.

The Model 530 has an in-line display for angular decimal readout, and is continuously switched through 360°.

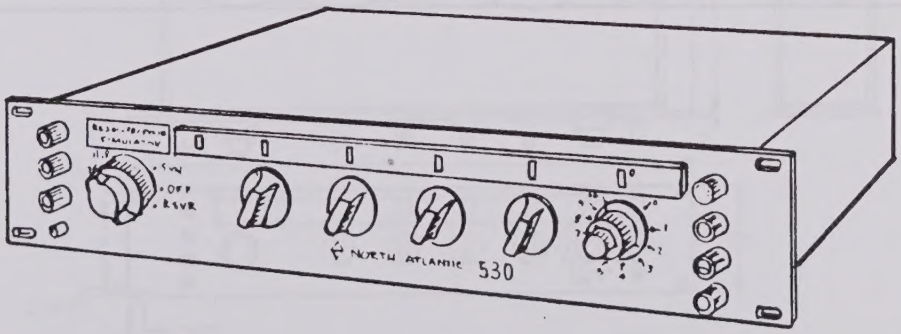

Figure 1-1. Synchro-Resolver Simulator, Model 530

*Accuracy of all North Atlantic Resolver-Synchro Simulators are verified by comparison to Ratio Standards which have records of calibrations traceable to the National Bureau of Standards.

1.4 SPECIFICATIONS

Table 1-1 provides characteristics and specifications for the Model 530.

Table 1-1. Specifications

Item	Specification
Excitation level	
26 volt terminals	0.07 f volt (f in Hz) 35 volts maximum
115 volt terminals	0.32 f volts (f in Hz) 150 volts maximum
Frequency range (within accuracy)	380 to 800 Hz
Frequency range (useful)	60 Hz to 10 kHz
Output voltage (line-to-line)	11.8, 26, 90, and 115 volts
Maximum load	500 mA
Accuracy (resolver and synchro modes)	±2 seconds of arc or ±0.00055°
Resolution	0.0001°
Maximum effective output impedance unbalance	0.05 + 0.03 ohm (max)
Output/input	All models are isolated
Size	3-1/2" panel x 19" W x 15-1/8" D
Weight	30 lbs. (approx.)

SECTION 2

INSTALLATION

The Model 530 is designed for either rack mounting or bench use. The compact 3-1/2" height and standard relay-rack width allows its installation into a large variety of test consoles with a minimum sacrifice of space. The all passive circuits used, generate no heat and, therefore, there need be no space allocated for cooling purposes.

An outline drawing of the Model 530 is illustrated in figure 2-1.

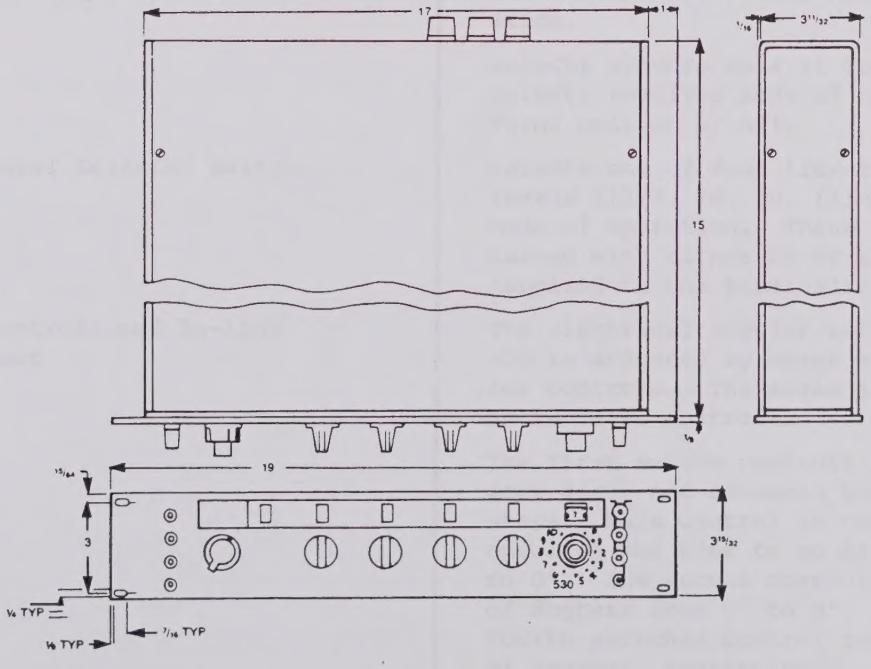

Figure 2-1. Model 530 Outline Drawing

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SECTION 3

OPERATION

3.1 GENERAL

This section provides operating instructions for the Model 530.

3.2 CONTROLS AND INDICATORS

The controls and indicators for the Model 530 are described in table 3-1 and illustrated in figure 3-1.

Table 3-1. Controls and Indicators

Control or indicator	Function
115 V, 26 V front and rear terminals	115 or 26 V excitation input applied to either front or rear of unit (high side).
COM	Low side of excitation input applied to front or rear terminal. (CASE should be placed at ground by either rack-mounting connection or a jumper from the COM terminal.)
Mode Selector switch	Selects synchro or resolver mode of operation.
SYN	Selects synchro mode of operation.
RSVR	Selects resolver mode of operation.
OFF	Turns unit on or off.
Line-to-Line Level Selector switch	Selects one of four line-to-line operating levels (11.8, 26, 90, 115 V) regardless of mode of operation. These levels are obtained with either 26 or 115 V excitation (applied to the terminals).
Angle Select controls and In-line Decimal Readout	The electrical angular setting of the Model 530 is adjusted by means of the Angle Selector controls. The angle is read directly above these controls. The first switch controls the most significant digit and advances the angle in 10° steps. This control is continuous (no stops) enabling the user to go directly from 350° to 0°. The second control controls the units of degrees from 0° to 9°. The third and fourth switches control tenths and hundredths of degrees, respectively. The fifth control consists of two concentric switches; the inner for increments of 0.001° with its readout in the window above the switch and an outer knob for increments of 0.0001° with its indicated setting screened on the panel.

Table 3-1. Controls and Indicators (Continued)

Control or indicator	Function
SYN and RSVR terminals (front and rear panel)	Three-wire synchro and four-wire resolver data available (front and rear panel) when Mode Selector switch is in SYN and RSVR position, respectively. By utilizing the rear panel terminals, the unit can be alternately switched from resolver to synchro operation without changing terminal connections.
1 and 5 A Slow Blow fuses	The unit is protected by a 1 A and a 5 A fuse which are in-series with the 115 V and 26 V excitation lines, respectively. These fuses are located on the rear panel.

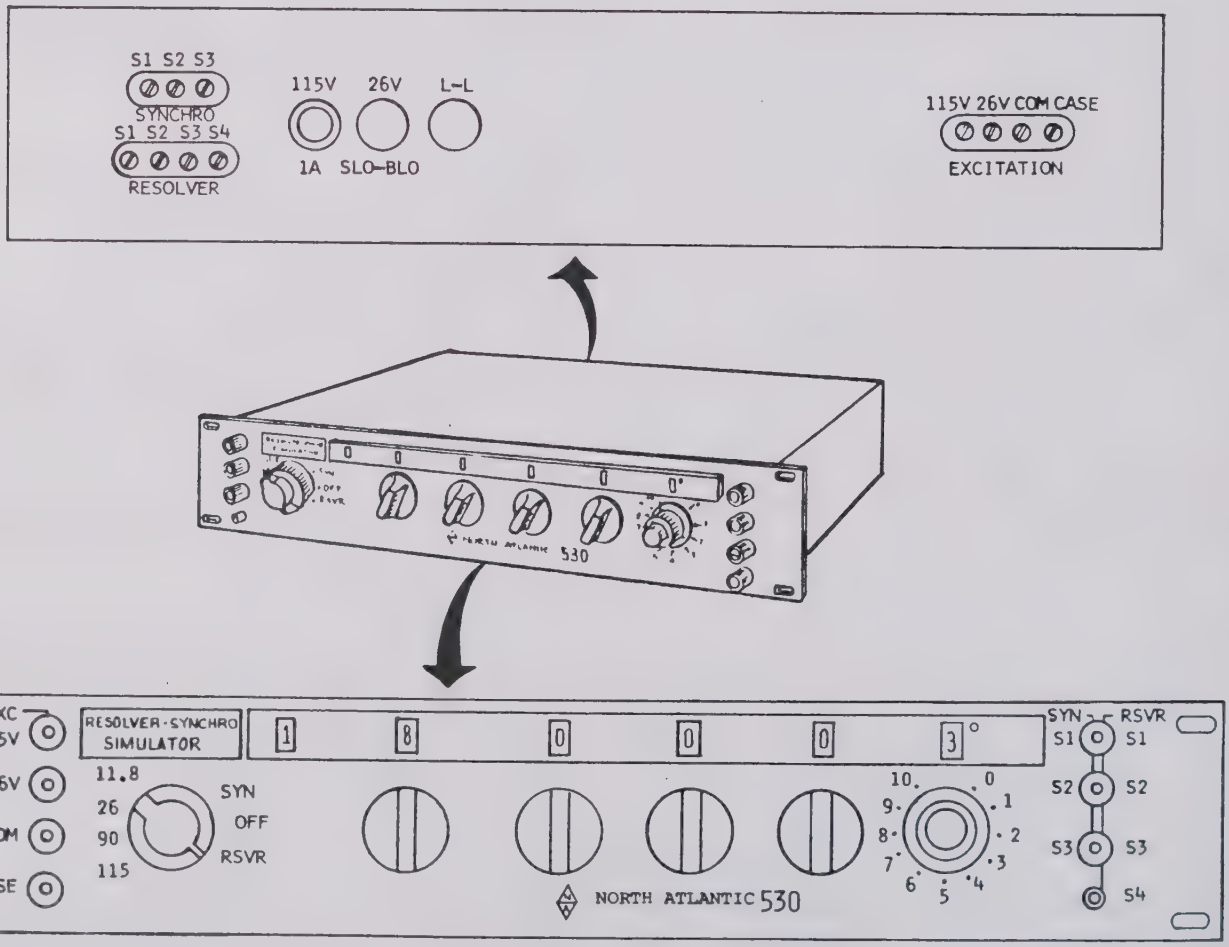

Figure 3-1. Controls and Indicators

3.3 APPLICATIONS

There are many methods in which the Model 530 can be used as a test instrument for evaluation, calibration, and alignment of resolver and synchro components, as well as systems employing these components. The following examples are meant to serve as a guide only. Many other applications in such areas as control circuit, phase shifters, etc., will no doubt occur to the user once familiar with the instrument's capability.

3.3.1 Finding the Unknown Data Angle of a Receiver Type Component Using a Full Resolution Simulator

a. With a hookup similar to that shown in figure 3-2, adjust the Model 530 Angle Select knobs to produce an approximately in-phase null on the phase angle voltmeter. The null meter phase shifter should be set at 0°.

b. Since the resolver or synchro receiver under test will have two positions which yield an in-phase null, it is necessary to remove this ambiguity as follows:

(1) While in the region of an approximate null, increase the angle setting of the Model 530. This will produce a more positive deflection on the phase angle voltmeter, if the correct angle has been found and if conventions are in accordance with Section 4 of this manual. If the reading is negative, increase the setting of the Model 530 by 180° and verify that the correct gradient polarity now occurs.

(2) Proceed with the nulling process by using the highest increment knobs first and continuing to the least significant knob. It will be necessary to down-scale the

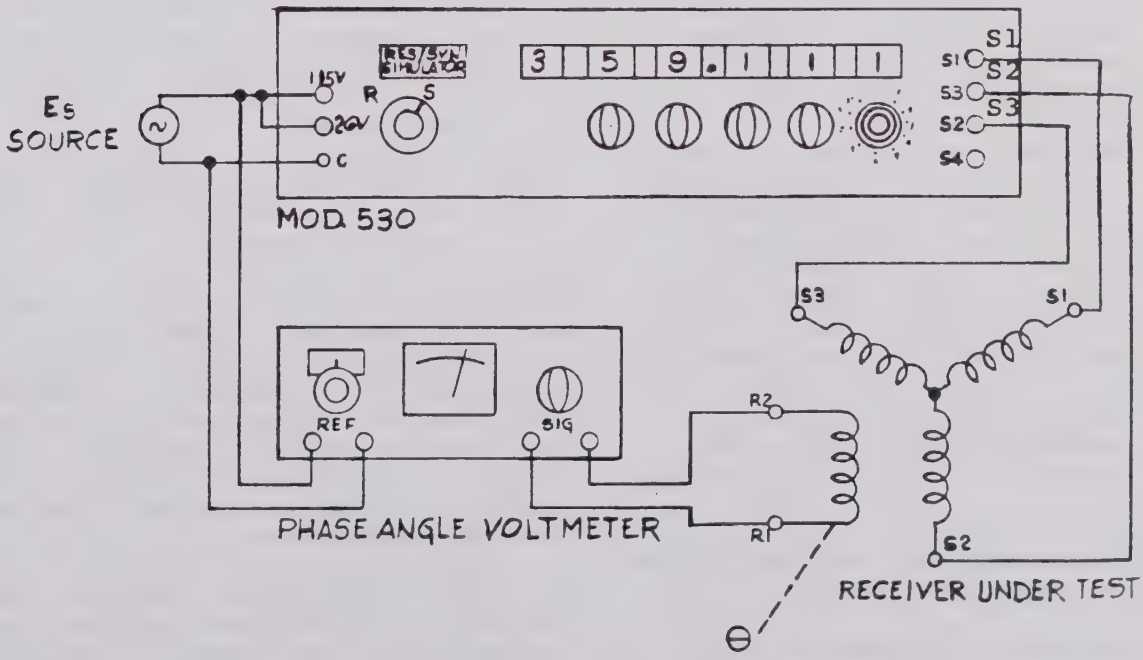

Figure 3-2. Typical Test Hook-up for Testing a Synchro Circuit

Phase Angle Voltmeter while these adjustments are being made in order to obtain maximum sensitivity.

(3) In the above measurement, it was indicated that the phase shifter of the null meter was set at 0° so as to produce a null in-phase with the line excitation. This method is consistent with the procedures of MIL-S-20708A.

c. An alternate null detector phase setting is sometimes used when the source of the null detector reference has an arbitrary phase relation to the synchros resolver excitation or where the component usage requires phasing in relation to the actual output signals. This procedure which is required by definition in MIL-R-21530C Resolvers, is as follows:

(1) With a (0° phase) null achieved as above, switch the Simulator to maximum output (90° + reading). Up range the null meter and observe the quadrature component at as large a meter deflection as possible. Now, offset the Model 530 by a large angle, but not enough to light the meter OVERLOAD lamp and observe that the quadrature reading changes slightly. The phase dial is now repositioned so as to restore the original quadrature reading. This, in effect, aligns the system to make measurements in-phase with the output. Since the actual setting would vary somewhat with mechanical position of the component under test, this procedure is usually done at zero mechanical degrees of electrical zero.

3.3.2 Adjusting a Receiver or System to a Predetermined Angle

a. With the Simulator connected to provide an input to the receiver under test, set the Angle Selector knobs so as to adjust the Model 530 to the desired angle. Then adjust the receiving resolver or synchro to obtain a null on the output of the receiver as evidenced either by an external phase angle voltmeter (fig. 3-2) or by some pre-established output of the system being aligned. For example, if a servo such as a North Atlantic API-8025 were being tested, the counter readout would be used to indicate the null position of the receiver shaft.

b. At this point, increasing the Model 530 angle will cause a positive change in resolver or synchro data and in the case of a system under test will cause the system output to increase providing the system or components are wired in accordance with the conventions of Section 4. If an opposite deflection occurs, the receiver being aligned is 180° in error and should be repositioned by this amount.

c. Note that in systems incorporating resolvers and synchros, the conventions of Section 4 are frequently altered to provide fixed offset angles or to reverse direction of rotation. The user must, therefore, verify the nature of the system's performance requirements before interpreting the results of the foregoing test.

3.3.3 Using the Phase Angle Voltmeter for Measuring Receiver Angular Error

This method is frequently used in testing synchro or resolver receivers where the inputs are in the form of discreet shaft angle increments. Typically, a component under test would be mounted in a device such as a dividing head. The Model 530 and dividing head would be set to 0° and the component positioned to 0° angle in the manner described in the previous paragraphs or by the electrical zero method of the applicable military specifications. Both the Model 530 and the dividing head are then advanced in the desired increments. The amplitude of the null voltage as measured on the output of the receiving component is related

to the error angle as follows:

$$E_{out} = K \sin (\theta - \phi)$$

$$\tilde{=} K (\theta - \phi), \text{ where}$$

K is gradient of device under test

$(\theta - \phi)$ is error angle of component

Since this relationship holds for small deviations at all angular settings whether the component is a resolver or a synchro, the null meter can easily be used to read a voltage which is proportioned to degrees, minutes, or seconds of arc.

As a matter of added convenience, a phase angle voltmeter, having a variable range attenuator, will permit the user to scale the null meter sensitivity such that the error angle can be read directly in degrees, minutes, or seconds from the meter itself.

SECTION 4

CONVENTIONS

4.1 GENERAL

Conventions for polarities, terminal designation, and direction of shaft rotation for synchros and resolvers are most frequency defined in accordance with military specifications MIL-S-20708A (synchros) and MIL-R-21530 (resolvers).

North Atlantic bridges and simulators all have terminal designations and electrical characteristics consistent with these same specifications. Thus, a bridge is used as though it were a receiving component such as a control transformer (CT or RC). Likewise, a simulator is comparable to a transmitting component (CX or RX).

In applying the conventions, caution must be exercized that:

- The manufacturer of the synchro or resolver followed the MIL SPEC conventions.
- System use of the component has not dictated a change in convention in order to achieve a difference in characteristic, such as direction reversal or mechanical shaft offset.

4.2 SYNCHRO TRANSMITTER CONVENTIONS

4.2.1 Synchro Transmitter (CX)

The equations describing an ideal Synchro Transmitter (CX) apply as well to the Model 530. They are:

$$E_{(S1-S3)} = NE_{(R2-R1)} \text{ Sin } \theta$$

$$E_{(S3-S2)} = NE_{(R2-R1)} \text{ Sin } (\theta + 120°)$$

$$E_{(S2-S1)} = NE_{(R2-R1)} \text{ Sin } (\theta + 240°)$$

Where: $E_{(R2-R1)}$ is the voltage between rotor leads R1 and R2.

$E_{(S3-2)}$ is the voltage between stator leads S1 and S2. Other voltages are similarly defined.

N is the ratio of the maximum rms voltage between the secondary terminals (stator) and the primary rotor voltage.

θ is the shaft angle displacement from electrical zero which satisfies these equations.

The schematic representation for a Synchro Transmitter (CX) is shown in figure 4-1.

NOTE

Synchro is shown at $\theta = E_Z$ (electrical zero). This is defined as that angle for which coupled voltage between the rotor and $E_{(S1-S3)}$ is a minimum.

4.2.2 Synchro Simulator

The input and output terminals of the Model 530 in the synchro mode correspond to figure 4-1 and are indicated in figure 4-2.

4.3 SYNCHRO RECEIVER CONVENTIONS

4.3.1 Synchro Receiver (CT)

The equations describing an ideal synchro receiver or control transformer (CT) apply as well to all Series 540 Bridges. They are:

$$E_{(R2-R1)} = N[E_{(S3-2)} \text{Sin}\theta - E_{(S1-S3)} \text{Sin}(\theta+120)]$$

$$\theta = E_{(S1-S3)} + E_{(S3-S2)} + E_{(S2-S1)}$$

Where, symbols have meaning defined in paragraph 4.2.1.

The schematic representation for a synchro-receiver (CT) is shown in figure 4-3.

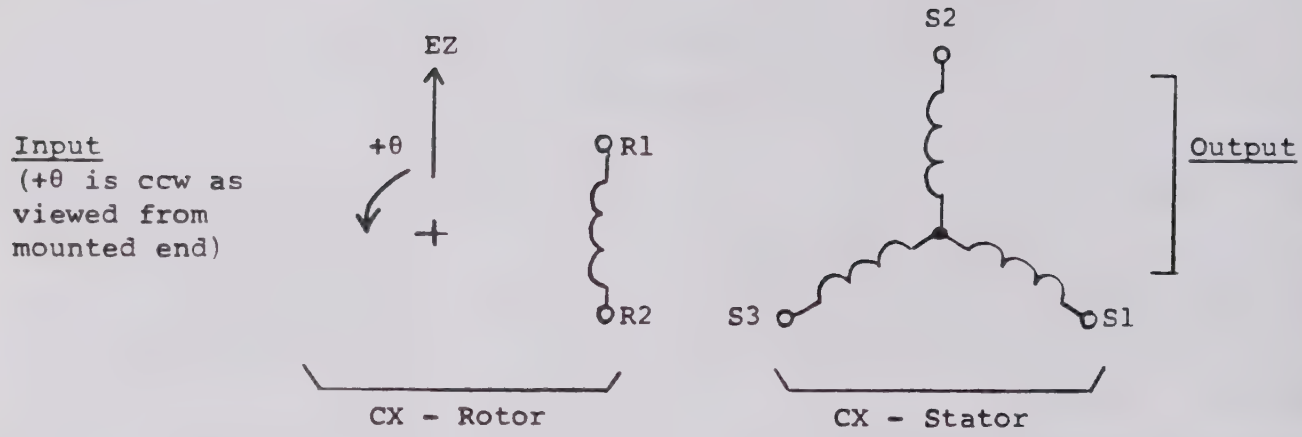

Figure 4-1. Synchro Transmitter (at EZ) - CX

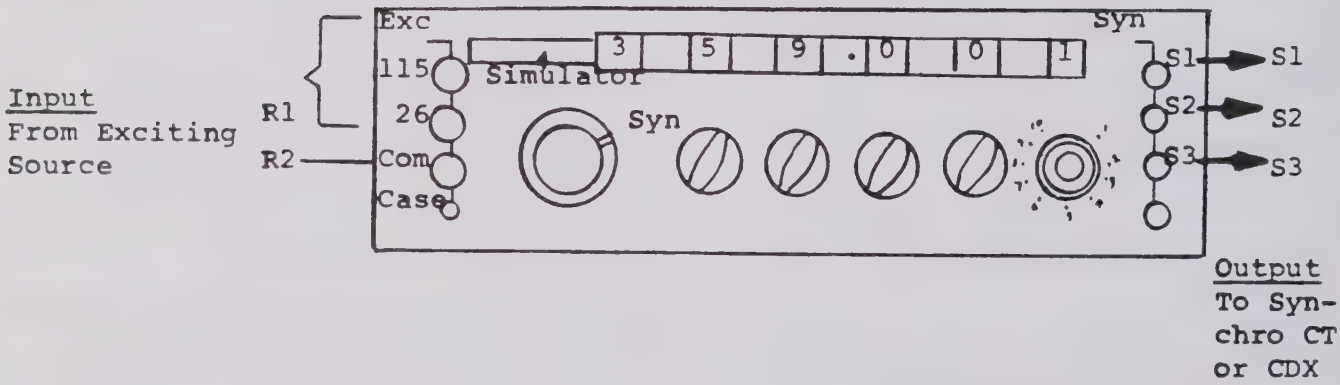

Figure 4-2. Model 530 - Synchro Mode

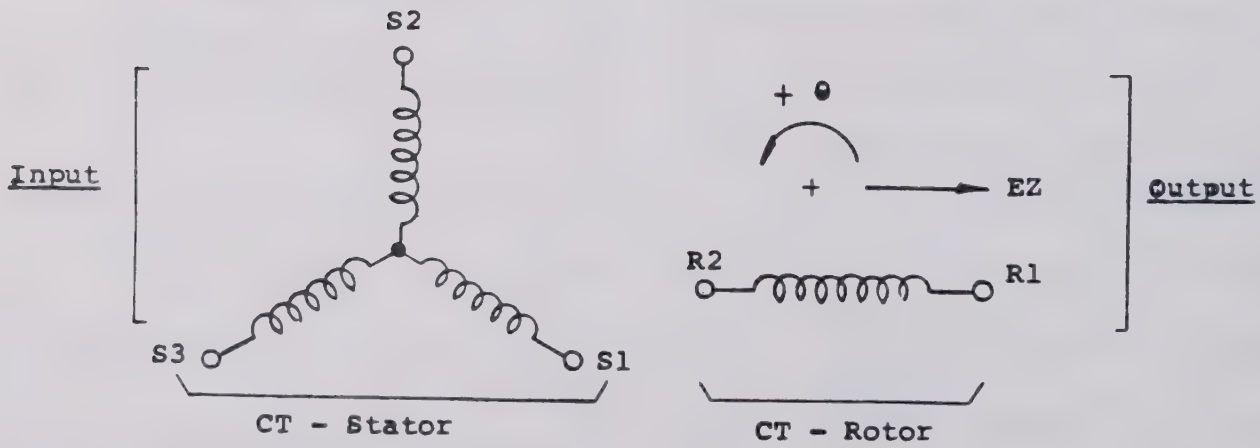

Figure 4-3. Synchro Receiver (at EZ) - CT

NOTE

Synchro is shown at $\theta = \theta_Z$ (electrical zero). This is defined as that angle for which the coupled voltage to the rotor is a minimum when the stators are excited between S2-S1, S3.

4.3.2 Synchro Bridge

The input and output terminals of a North Atlantic Series 540 Bridge in the synchro mode are analogous to those of a synchro receiver (CT). The connections which correspond to figure 4-3 are shown in figure 4-4.

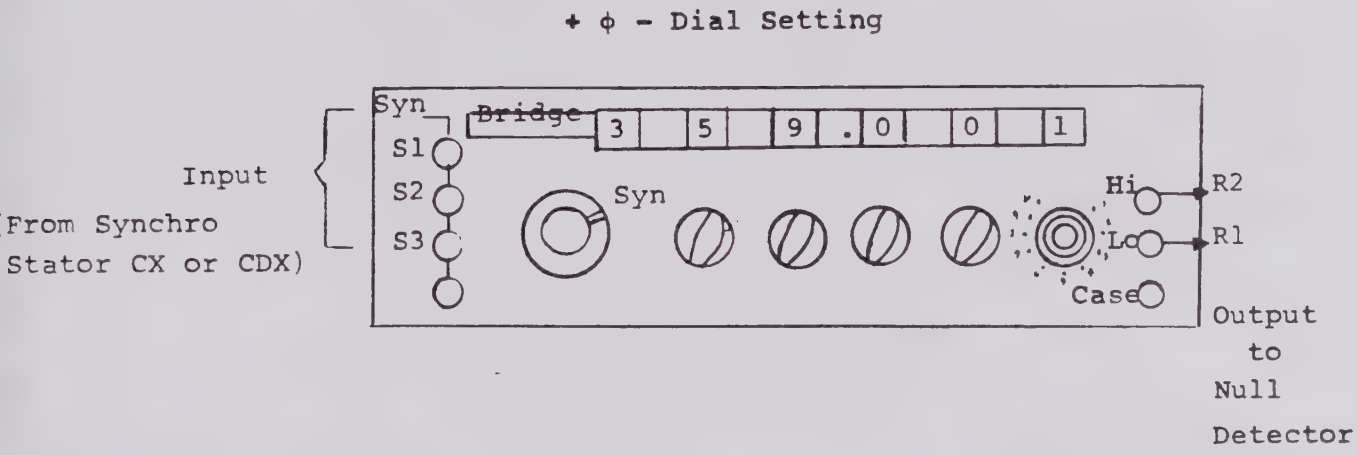

Figure 4-4. Model 540 Bridge - Synchro Mode

4.4 RESOLVER CONVENTIONS

4.4.1 Resolver Transmitter (RX), Control Transformer (RC), and Differential Resolver (RD)

The equation describing an ideal resolver apply as well to all Series 540 Bridges and 530 Simulators. They are:

For Rotor Energized Resolvers:

$$E_{(S1-S3)} = NE_{(R1-R3)} \cos\theta - NE_{(R2-R4)} \sin\theta$$

$$E_{(S2-S4)} = NE_{(R2-R4)} \cos\theta + NE_{(R1-R3)} \sin\theta$$

For Stator Energized Resolvers:

$$E_{(R1-R3)} = NE_{(S1-S3)} \cos\theta + NE_{(S2-S4)} \sin\theta$$

$$E_{(R2-R4)} = NE_{(S2-S4)} \cos\theta - NE_{(S1-S3)} \sin\theta$$

Where, symbols have meaning defined in paragraph 4.2.1.

The schematic representation for a Resolver Transmitter (RX), Resolver Control Transformer (RC), or a Differential Resolver (RD) with the rotor excited is shown in figure 4-5. Input and output can be reversed for stator excited schematic.

NOTE

Resolver is shown at θ = EZ (electrical zero). This is defined as a minimum coupling from (R1-R3) to (S2-S4) for rotor excited case. For stator excited resolver EZ is defined for minimum coupling from (S1-S3) to (R2-R4).

4.4.2 Resolver Simulator

The input and output terminals of the Model 530 simulator in the resolver mode is analogous to that of a rotor excited Resolver Transmitter (RX). The connections which correspond to those shown in figure 4-5 are illustrated in figure 4-6 for a Model 530 Simulator in the resolver mode.

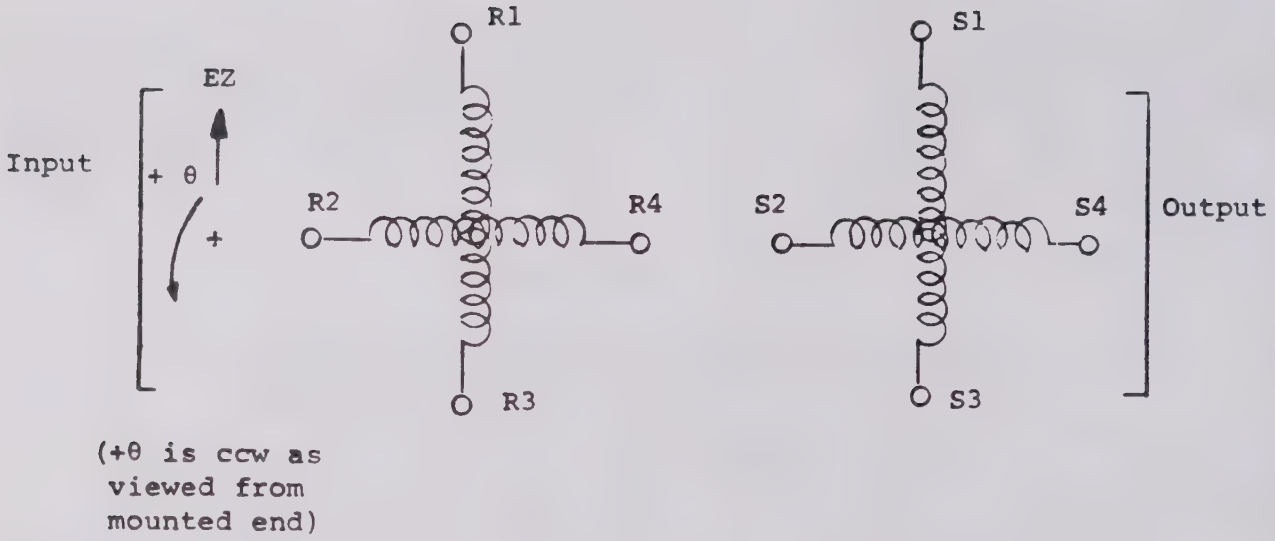

Figure 4-5. Rotor Excited Resolver at EZ, RX, RC, or RD

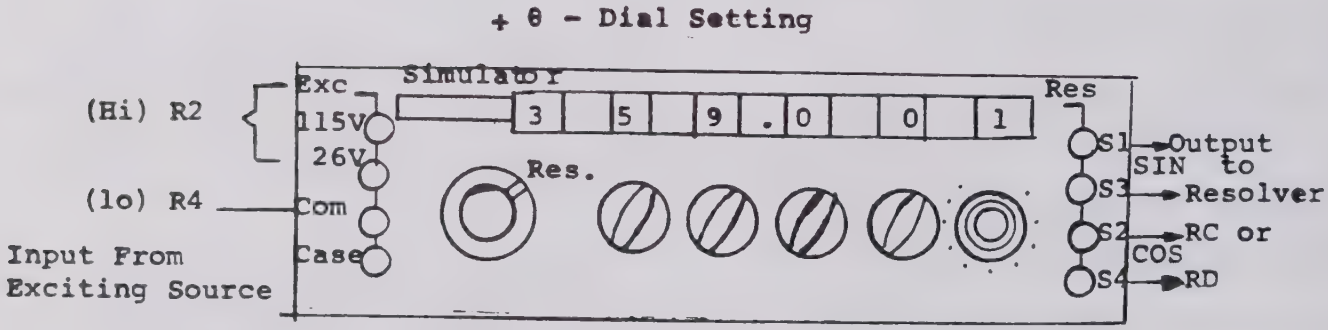

Figure 4-6. Model 530 Simulator - Resolver Mode

Alternate Resolver Simulator conventions (all assume CCW is positive rotation) are shown in figure 4-7.

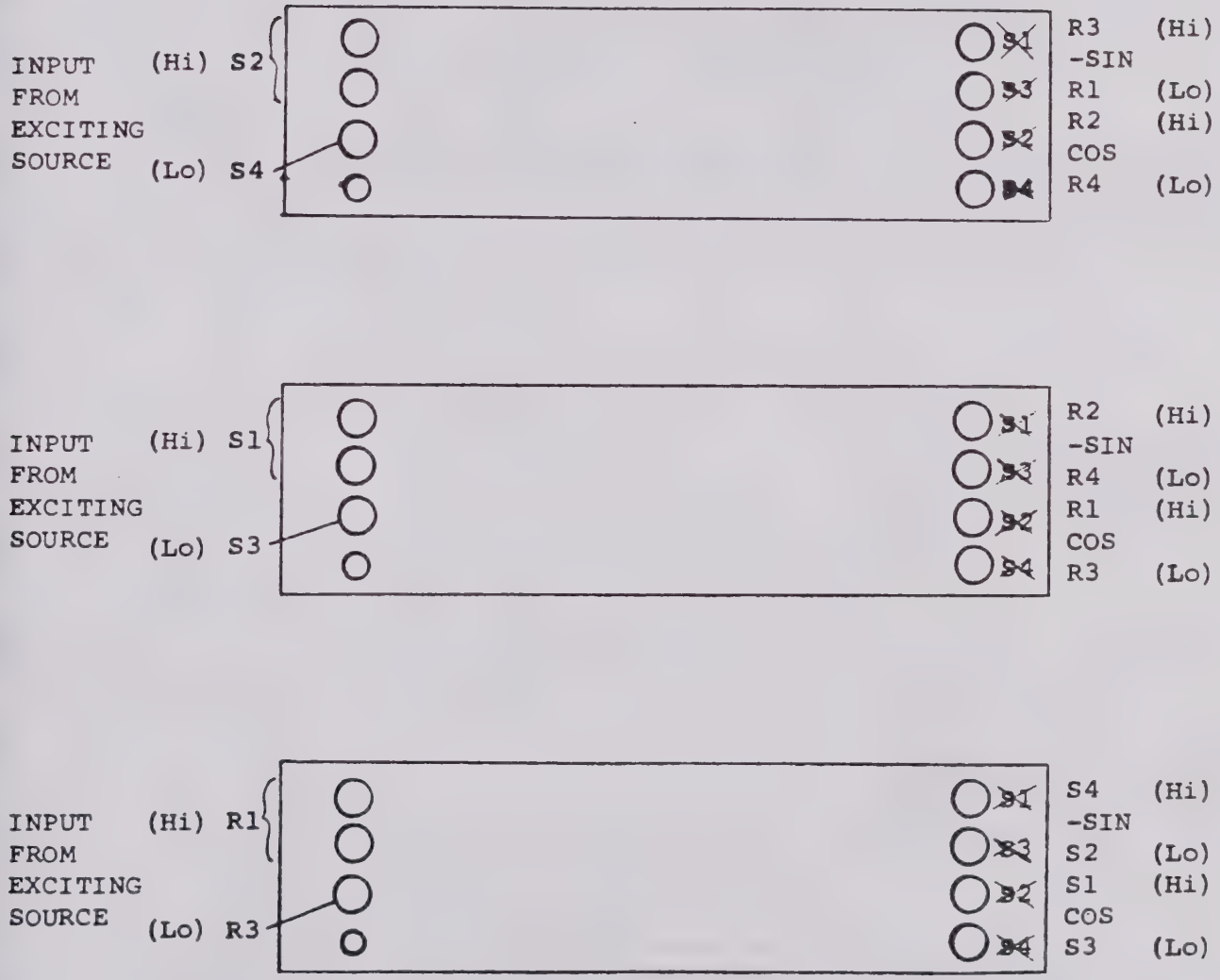

Figure 4-7. Model 530 Simulator - Resolver Mode (Alternate Convention)

4.5 RESOLVER BRIDGE

The input and output terminals of the North Atlantic Series 540 Resolver Bridge in the resolver mode are analogous to those of a stator excited resolver Control Transformer (RC). The connections which correspond to those shown in figure 4-5 are illustrated for a Model 540 Bridge in figure 4-8.

Alternate Resolver Bridge conventions (all assume CCW is positive rotation) is illustrated in figure 4-9.

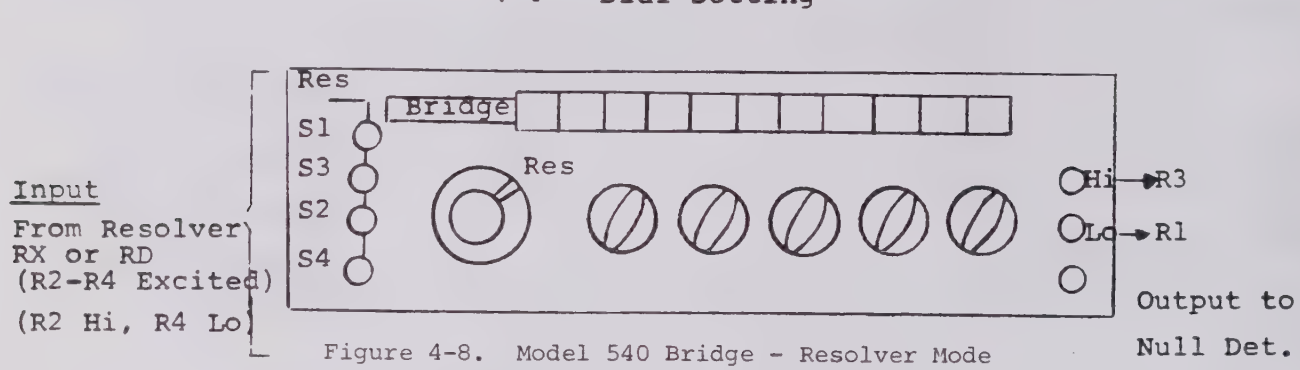

Figure 4-8. Model 540 Bridge - Resolver Mode

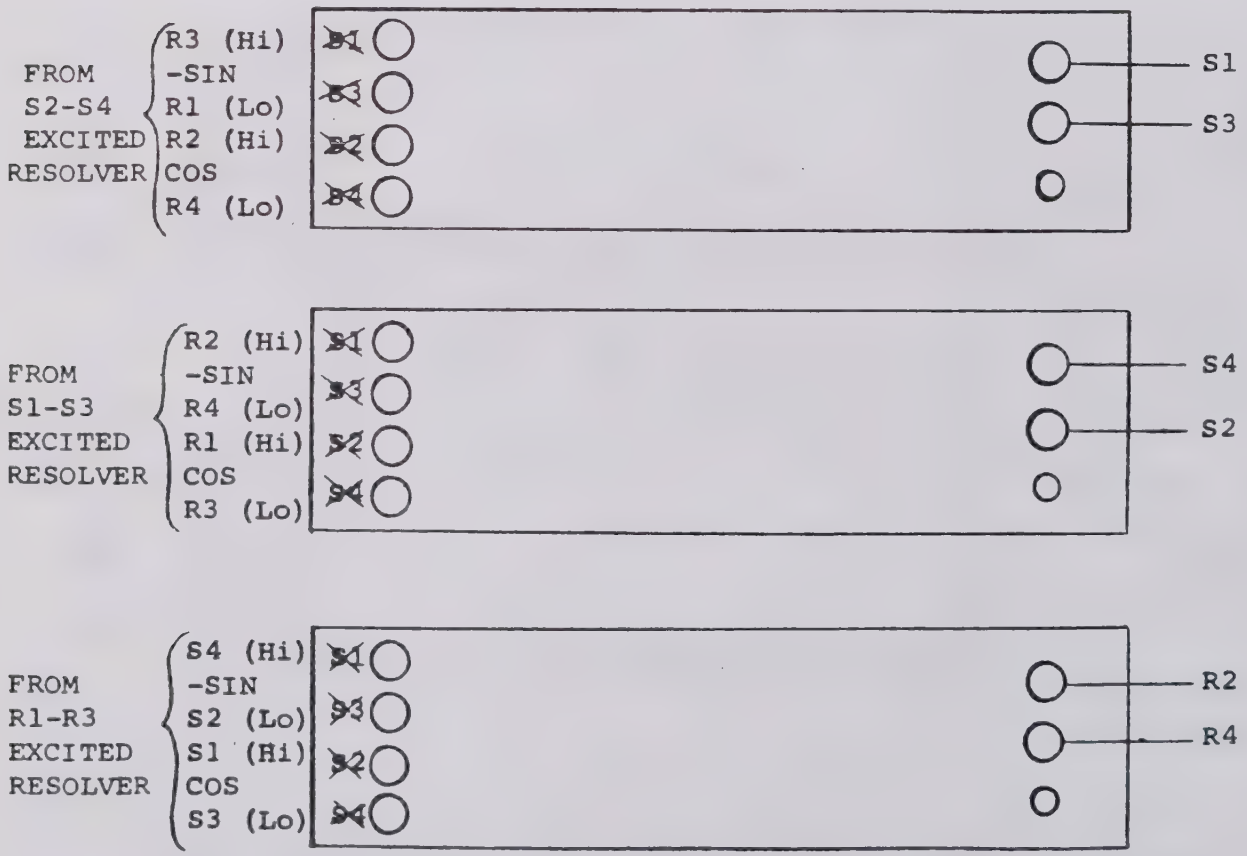

Figure 4-9. Model 540 Bridge - Resolver Mode (Alternate Convention)

SECTION 5

THEORY OF OPERATION

5.1 GENERAL

The Model 530 basically consists of three transformer sections. The first, or Input section, utilizes a tapped transformer which can be switched to provide the various line-to-line output voltage levels. The second section, called the Trigonometric Divider section, produces two outputs precisely proportional to the sine and cosine of the angle selcted by a series of front panel switches. The third section is a Form Converter section which produces, at the output terminals, isolated synchro (3 wire) or resolver (4 wire) data at very low impedance levels.

5.2 BLOCK DIAGRAM DESCRIPTION

Refer to figure 5-1 for the following description.

The excitation signal, 115 V or 26 V, is applied to a tapped auto-transformer from which the desired line-to-line output level can be selected via switch S_A.

The output of the input voltage selection circuit is used to excite a pair of trigonometric divider sets. Each divider set produces a ratio equivalent to the sine or cosine of the angle set into the Model 530 by the front panel knobs.

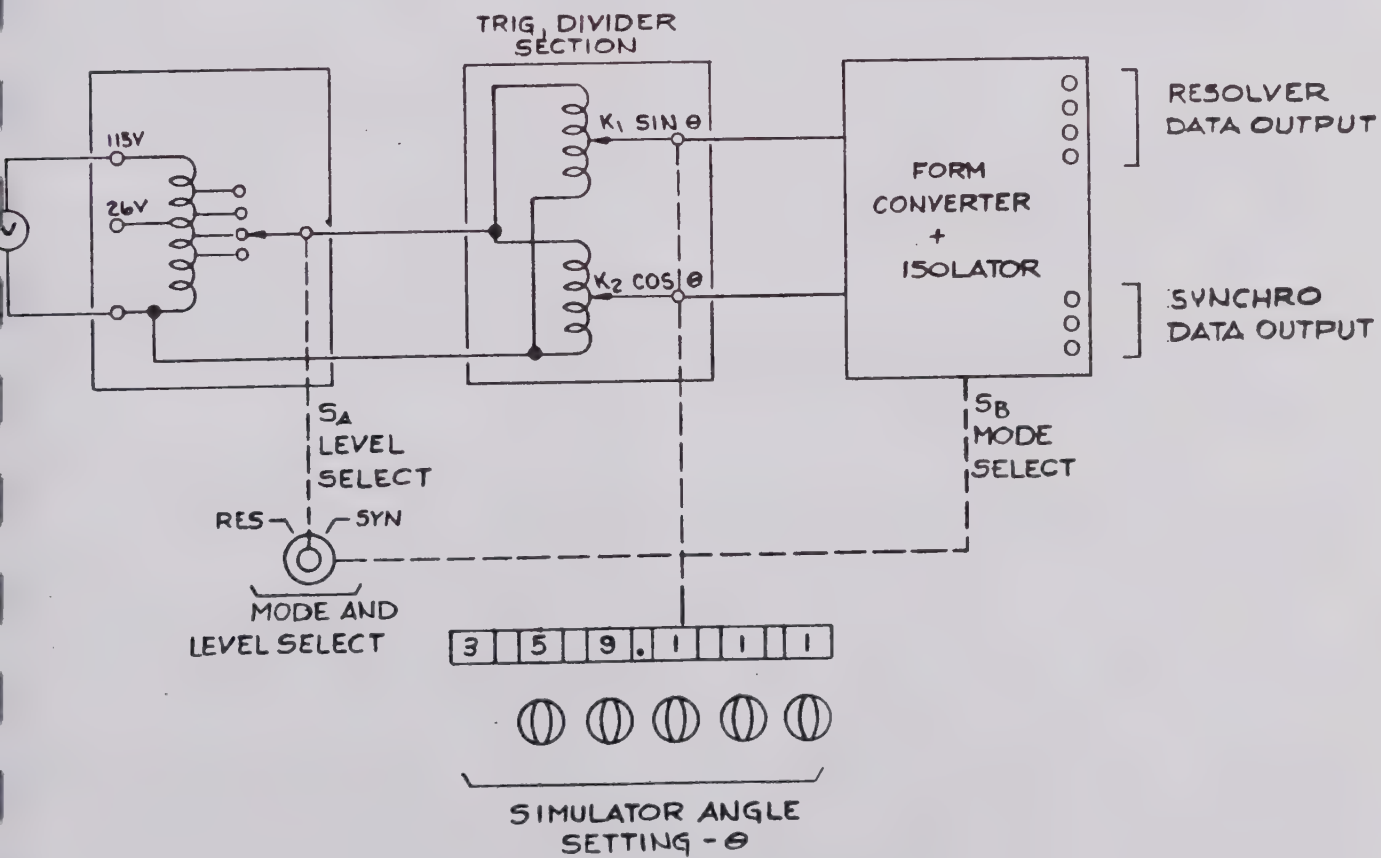

Figure 5-1. Model 530 Block Diagram

Each divider consists of a series of precision tapped toroidal transformers arranged in a novel circuit (patents applied for) which facilitates the precise interpolation of the angular data.

The outputs of these independent divider chains are applied, in turn, to the Form Converter which is comprised of several precisely matched toroidal transformers. The Form Converter presents as an output either 3-wire synchro data or 4-wire resolver data depending upon the circuit arrangement selected by the Mode Selector switch S_B.

Both Resolver and Synchro modes provide outputs which are isolated from the input excitation.

It is important to realize that the open circuit data output from the Model 530 is defined in terms of the ratio of the output signals. For the Resolver mode, the two outputs are:

$$E_{S1-S3} = K_1 \text{ Sin } \theta$$

$$E_{S2-S4} = K_2 \text{ Cos } \theta$$

Since $K_1 = K_2$, to an accuracy of 1 or 2 ppm, then:

$$\frac{E_{S1-S3}}{E_{S2-S4}} = \text{Tan } \theta$$

Thus, the output ratio defines the tangent of the selected input data angle to the accuracy specified for the unit.

Similarly, the data angle is defined for an ideal synchro in terms of the ratio of any two of the three output voltages:

$$E_{S1-S3} = K_1 \text{ Sin } \theta$$

$$E_{S3-S2} = K_2 \text{ Sin } (\theta + 120°)$$

$$E_{S2-S1} = K_3 \text{ Sin } (\theta + 240°)$$

Again, since $K_1 = K_2 = K_3$ to an accuracy of 1 or 2 ppm, the ratio of any two will define the angle in accordance, with the expression:

$$\frac{E_{S1-S3}}{E_{S2-S1}} \quad \frac{\text{Sin } \theta}{\text{Sin } (\theta + 240°)}$$

Note that since any two of the three synchro voltages will determine the third by Kirchoff's Law, there are, therefore, two other redundant equations relating the data angle, θ, to voltage ratios.

An important aspect of any simulator is the effect of a load on the accuracy of the ratios just described. The Model 530 has low nominal output impedances which minimize the effect of a load on the unit. Further, the design provides for a careful match of output impedance such that the effect of a load impedance is even further reduced, being related to the impedance unbalance rather than the absolute level.

The actual relationship of impedance unbalance and load is quite complex and is a function of not only the unbalance impedanc but also the data angle itself. This is apparent if it is noted that an unbalance impedance would not be equally important for all ratios; for example, in the limiting case of an angle defined by a ratio of zero, neither load impedance nor unbalance impedance could change the ratio.

5.3 SWITCHING

The Model 530 contains inductive transformer sets which performs a basic 10° interpolation followed by succeeding decades of interpolation for 1°, 0.1°, 0.01°, 0.001°, and 0.0001°.

The first or 10° switch is a unique design original in North Atlantic equipment, whic links the 10° knob to both a 350° total display range and a 90° quadrant switch (not displayed). By using this technique, an in-line, non-ambiguous display of 0° to 350° in 10° increments with a direct return to zero is possible with no direction reversal and no need to mentally add dial readings.

All switches are designed with heavy-duty silver alloy buttons for long life and have transient suppression resistors mounted directly on the switch decks.

SECTION 6

MAINTENANCE

6.1 GENERAL

This section contains periodic maintenance and calibration procedures for the Model 530. The Model 530 contains highly accurate inductive circuits. Under normal operating conditions, the accuracy of these devices should remain within specified tolerances indefinitely.

6.2 DEGAUSSING

If dc has been applied to any of the terminals in the Model 530, the instrument may be degaussed by attaching the circuit shown in figure 6-1 to all input terminal pairs in sequence. For dual-mode degaussing, the three synchro inputs will cover both modes.

With all knobs set at zero, apply the 60 Hz voltage to the instrument by slowly raising from zero until the point at which saturation occurs.

This will be evidenced when further increasing the setting of the Variac results in a relatively small increase in the voltage applied across the instrument. Allow the instrument to remain under the saturated conditions for a short period (typically 5 to 10 minutes). Then, slowly, over about the same period, reduce the voltage to the instrument to zero. Any residual magnetism which had been stored in the core by the dc should now be removed and the instrument should function properly. If the instrument still does not function with the specified tolerance, it should be returned to the factory.

6.3 SWITCHES

All switches used for switching critical inductive circuits are designed for long life using heavy duty alloy button contacts.

For normal maintenance, switch contacts should be cleaned with a good grade solvent, such as alcohol, and relubricated with a very thin film of clean switch lubricant, such as petroleum jelly, every 4 to 6 months of use.

If an instrument has not been used for an extended period of time, it may be desirable to cycle switches several times so as to wipe contacts clean prior to making measurement. This routine can be considered normal for an instrument of this type.

Should a precision switch need to be replaced, remove all wire connections by carefully sliding female Malco type wire

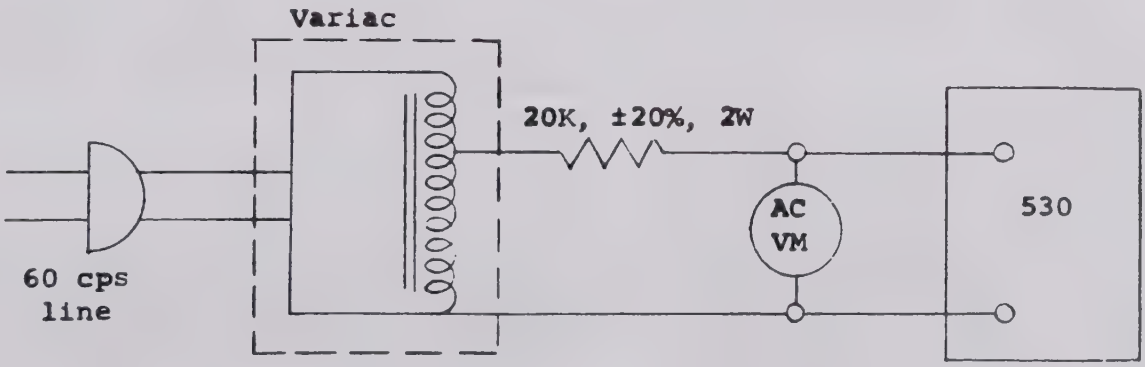

Figure 6-1. Degaussing Circuit

connectors away from switch deck. This is readily accomplished by using a pair of long-nose pliers.

CAUTION

Do not unnecessarily remove Malco terminals since excessive disassembly may impair self-clinching characteristic of the connector.

6.4 TRANSFORMERS

If a malfunction occurs which indicates that a transformer component is faulty, return the unit to the factory for overhaul and recalibration.

6.5 CALIBRATION

Routine recalibration of the Model 530 is normally not required except insofar as the customer quality assurance methods require these checks so as to be certain that no random failures have caused the instrument to malfunction.

The philosophy governing the calibration of a resolver-synchro simulator or bridge and the establishing of meaningful standards involves considerations similar to those encountered in the area of ac ratio boxes.

In both cases, calibration data is a matter of ratio accuracy. For the ratio box, it is the ratio of the output to the input. For the resolver bridge or simulator, it is the ratio of two ac voltages, while for a synchro bridge or simulator, it is the ratio of any two of the three line-to-line voltages.

Thus, ratio is the all important measurement and herein lies the need for an appreciation of the difference between ratio certainty and a standard as defined by the Bureau of Standards. Ac ratio is not uniquely related to, or logically measurable in terms of, the usual physical concepts of mass, length, or time since it is a dimensionless quotient. As such, it is not traceable to any absolute electrical standard such as the ohm, volt, or ampere. Ac ratio, by its nature, can be known to an almost unlimited degree of precision depending upon the ingenuity of the person making the measurement and the stability of the equipment used. Typically, in the area of ac ratio measurements, measurements have been made at the National Bureau of Standards, as well as in industry, to precision in order of 0.01 ppm and better. Yet, at this time, no known set of circuit elements could be assembled into a single instrument which would provide a certainty of measurement of this order of magnitude for a reasonable range of voltages, temperature, frequency, ratio, or time. This, in effect, represents the present state of the art in ac ratio measurements.

Since the technique of ac ratio measurement is considerably better than any commercially available ratio reference, it must be readily apparent that an inductive ratio box, rated at 1.0 ppm accuracy, can be evaluated or calibrated so as to provide confidence in this rating over a reasonable period of time and under the rated conditions of voltage, frequency, temperature, and ratio range. The National Bureau of Standards provides such a calibration service and evidences their calibration in the form of a record of calibration as of the time the ratios were measured. It remains for the user and manufacturer to determine the period over which confidence in this rating can be maintained.

It is the experience of North Atlantic, over a period of many years, that a properly maintained inductive ratio device such as a ratio box, bridge, or simulator, will sustain its ratio accuracy to a confidence level of well under 1.0 ppm for a period of many years.

6.5.1 Simulator and Bridge Calibration

In the following procedure, a technique for calibrating both resolver-synchro simulators and bridges is presented which follows the philosophy just described. Through use of a ratio box, it is merely a matter of technique by which both bridges and simulators

can be calibrated to a level of confidence comparable to the ratio reference inself. Noting that an uncertainty in ratio, equivalent to ±1.0 ppm (against unity ratio) is, in the worst case, equivalent to an angular uncertainty of only ±0.2 arc second, it is apparent that a high degree of confidence can be expected in the ultimate calibration data for resolver and synchro bridges and simulators.

6.5.2 Calibration Period and Method

The frequency of calibration required for resolver-synchro bridges and simulators is necessarily dictated by the application and the established policies of the user. Since the construction of all North Atlantic bridges and simulators uses heavy-duty switches and quality torroidal transformers, it is recommended that full calibration (para. 6.5.4) will only infrequently be required. However, where quality control procedures require routine checks to make certain that no random equipment failures have occurred, the simpler calibration procedure (para. 6.5.3) may be used.

6.5.3 Calibration Procedure I

6.5.3.1 General

This procedure can be used to calibrate, on a go-no-go basis, either a bridge or a simulator. The validity for this type of comparison can be taken as the sum of the rated bridge error and the rated simulator error or ±4 arc seconds. The procedure is recommended as a routine quality control calibration to verify proper operation of the equipment.

6.5.3.2 Equipment Required

Equipment required for Calibration Procedure I is listed below:

Qty	Equipment
1	North Atlantic Resolver-Synchro Bridge, Model 540, or Resolver-Synchro Simulator, Model 530
1	North Atlantic Phase Angle Voltmeter, Model 213C, 321, or 225
1	Adjustable source of 400 Hz ac voltage

6.5.3.3 Procedure

a. Connect equipment as shown in figure 6-2.

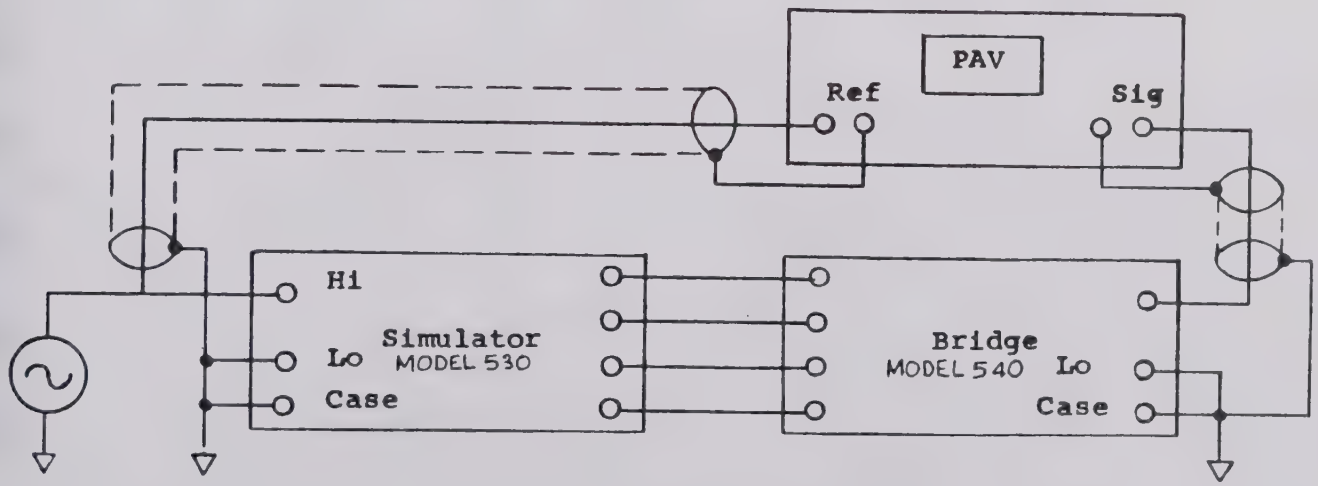

Figure 6-2. Calibration Hookup

b. Using appropriate reference simulator or bridge, adjust all knobs to read zero on both the test item and the reference equipment.

c. Adjust power supply to 26 V or 115 V, 400 Hz depending upon simulator input terminal used.

d. Adjust the phase angle voltmeter to read an in-phase null (Section 3).

e. Offset either the simulator or bridge by 0.02° or 72 seconds. Select convenient meter range where range vernier permits adjustment of reading to 72 on X10 scale. Meter is now appropriately scaled to measure the deviation between the bridge and simulator directly in seconds by ranging to any convenient scale.

f. Track both simulator and bridge through desired calibration angles, noting that readings all fall within ±4 arc seconds.

g. If in step f above, readings fall outside the ±4 second spread, recheck operation of the PAV and test circuit to be certain the hookup is correct and that no ground loops, unground terminals, etc., exist. If the out-of-tolerance reading is reaffirmed, proceed to paragraph 6.5.4.

6.5.4 Calibration Procedure II

6.5.4.1 General

This calibration procedure is designed to provide what might be thought of as an ideal calibration. In the case of a bridge, means are taken to eliminate any errors due to loading of the source impedances by the bridge. In the case of the simulator, the calibration method closely approximates the conditions of a simulator driving a high impedance load, thereby providing an ideal open-circuit accuracy.

The procedure is arranged in two parts. The first covers the calibration of a resolver bridge and a synchro bridge to a ratio measurement validity of approximately ±1.0 ppm or the equivalent of a ±0.2 arc seconds.

The second part of this procedure makes use of a bridge calibrated in accordance with the above. The bridge is then used as a calibrated transfer reference against which a resolver or synchro simulator can be calibrated. This procedure results in a validity of calibration of approximately ±0.4 arc seconds for a simulator.

A word of caution should be made regarding the use of alternate methods of calibration such as those using a resistance bridge or methods utilizing single ratio box techniques. Although good results may be obtainable, insidious errors due to impedance loading, phase shift, etc., are easily overlooked. The procedures described are recommended principally because the simplicity of the setup does not need a particularly high degree of ingenuity or experience to achieve the accuracy sought.

6.5.4.2 Resolver Bridge Calibration

The following procedure can be used to calibrate all Model 540 and 541 Resolver Bridges.

6.5.4.2.1 Equipment Required

Equipment required for resolver/bridge calibration is listed below:

Qty	Equipment
2	10 ppm Ratio Box
1	1.0 ppm Ratio Box
1	Shielded Bridge - Null Transformer
2	Phase Angle Voltmeter, North Atlantic Model 213C, 321, or 225
2	DPDT switch
1	Adjustable source of 400 Hz ac voltage

6.5.4.2.2 Procedure

a. Connect equipment as shown in figure 6-3.

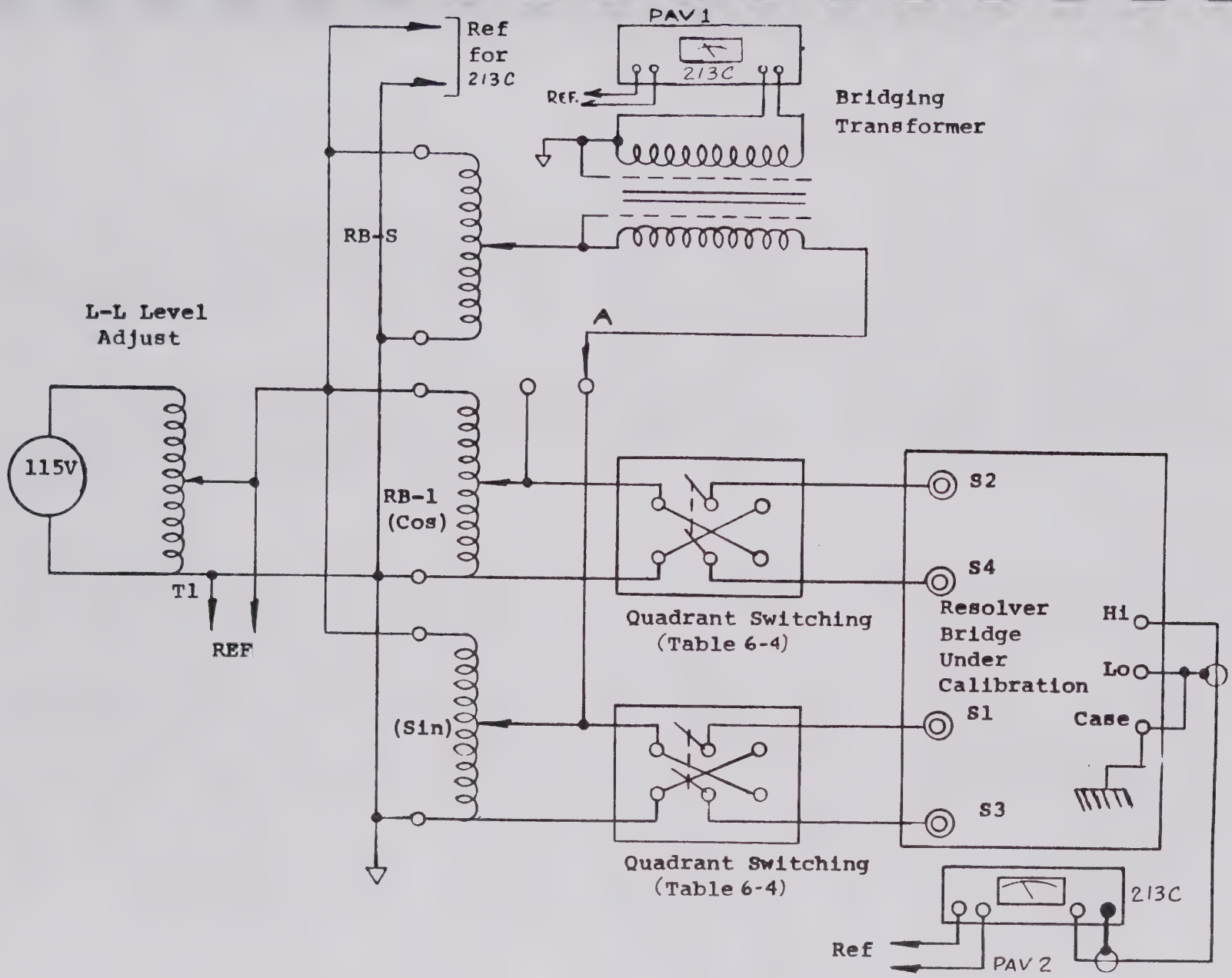

Figure 6-3. Resolver Bridge Calibration Hookup

NOTE

In this arrangement, ratio boxes RB-1 and RB-2 serve to generate resolver voltages suitable for driving the inputs of the bridge being calibrated.

Since these boxes have finite output impedance which vary with ratio settings, some loading errors can be expected due to the input impedance of the bridge being tested.

To correct for this loading error, the 1.0 ppm ratio box designated RB-S is used as a precision ratio transfer device. Ratios can be set up on RB1 and RB2 while under load. The bridge null transformer and phase angle voltmeter No. 1, are used to make the comparison between the ratio reference, RB-S, and the driving ratio boxes, RB1 and RB2.

b. Adjust Variac T-1, or variable source for desired line-to-line voltage (90, 11.8, etc.) to accuracy of ±5%.

c. Adjust phase angle voltmeter No. 1 for an in-phase null (0°).

d. With resolver bridge under test set at the angle being calibrated, set RB-S to desired sine (RB-2) ratio, using values from tables 6-1 through 6-6.

e. Connect null transformer lead A to the output of ratio box RB-2 and adjust for null on phase angle voltmeter No. 1. Set to resolution of at least 1/3 ppm.

f. Repeat steps c and d for setting ratio box RB-1.

g. Input to bridges is now accurate to within ±0.2 s. Now adjust bridge to achieve in-phase null on phase angle voltmeter No. 2. Read and record calibration angle from bridge.

h. Repeat steps d through g for each angle to be calibrated. Note that tables 6-1 through 6-6 are given for the most commonly tested angles.

Table 6-1. Resolver Calibration - 0° to 360° (5° Increments)

Quad. I	Quad. II	Quad. III	Quad. IV	RB 1	RB 2
0°	180°	180°	360°	1.0000000	.0000000
5°	175°	185°	355°	.9961946	.0871557
10°	170°	190°	350°	.9848077	.1736480
15°	165°	195°	345°	.9659258	.2588190
20°	160°	200°	340°	.9396926	.3420201
25°	155°	205°	335°	.9063077	.4226182
30°	150°	210°	330°	.8660254	.5000000
35°	145°	215°	325°	.8191520	.5735764
40°	140°	220°	320°	.7660444	.6427876
45°	135°	225°	315°	.7071067	.7071067
50°	130°	230°	310°	.6427876	.7660444
55°	125°	235°	305°	.5735764	.8191520
60°	120°	240°	300°	.5000000	.8660254
65°	115°	245°	295°	.4226182	.9063077
70°	110°	250°	290°	.3420201	.9396926
75°	105°	255°	285°	.2588190	.9659258
80°	100°	260°	280°	.1736480	.9848077
85°	95°	265°	275°	.0871557	.9961946
90°	90°	270°	270°	.0000000	1.0000000

Table 6-2. Resolver Calibration
40° to 49°
(1° Increments)

Angle	RB1 (Cos)	RB2 (Sin)
40°	.7660444	.6427876
41°	.7547096	.6560590
42°	.7431448	.6691306
43°	.7313537	.6819984
44°	.7193398	.6946584
45°	.7071068	.7071068
46°	.6946584	.7193398
47°	.6819984	.7313537
48°	.6691306	.7431448
49°	.6560590	.7547096

Table 6-3. Resolver Calibration
40.1° to 40.9°
(0.1° Increments)

Angle	RB1 (Cos)	RB2 (Sin)
40.1°	.7649214	.6441236
40.2°	.7637960	.6454577
40.3°	.7626683	.6467898
40.4°	.7615383	.6481199
40.5°	.7604060	.6494480
40.6°	.7592713	.6507742
40.7°	.7581343	.6520984
40.8°	.7569951	.6534206
40.9°	.7558535	.6547408

Table 6-4. Resolver Calibration
40.01° to 40.09°
(0.01° Increments)

Angle	RB1 (Cos)	RB2 (Sin)
40.01°	.7659322	.6429213
40.02°	.7658200	.6430550
40.03°	.7657078	.6431886
40.04°	.7655955	.6433223
40.05°	.7654832	.6434559
40.06°	.7653709	.6435895
40.07°	.7652586	.6437230
40.08°	.7651461	.6438566
40.09°	.7650338	.6439901

Table 6-5. Resolver Calibration
40.001° to 40.009°
(0.001° Increments)

Angle	RB1 (Cos)	RB2 (Sin)
40.001°	.7660332	.6428010
40.002°	.7660220	.6428143
40.003°	.7660107	.6428277
40.004°	.7659995	.6428411
40.005°	.7659883	.6428545
40.006°	.7659771	.6428678
40.007°	.7659659	.6428812
40.008°	.7659546	.6428946
40.009°	.7659434	.6429073

Table 6-6. Resolver Calibration - Quadrant Switching

Quadrant	Angle	Hi	Lo	Hi	Lo
I	0-90°	S2	S4	S3	S1
II	90-180°	S4	S2	S3	S1
III	180-270°	S4	S2	S1	S3
IV	270-360°	S2	S4	S1	S2

6.5.4.3 Synchro Bridge Calibration

6.5.4.3.1 Equipment Required

The same test equipment is required as in paragraph 6.5.4.2.1 except that three SPDT switches are needed.

6.5.4.3.2 Procedure

Connect equipment as shown in figure 6-4.

NOTE

In this arrangement ratio boxes RB-1 and RB-2 serve to generate synchro input voltages suitable for driving the inputs of the bridge being calibrated. Since these boxes have finite output impedances which vary with ratio settings, some loading errors can be expected due to the input impedance of the bridge being tested.

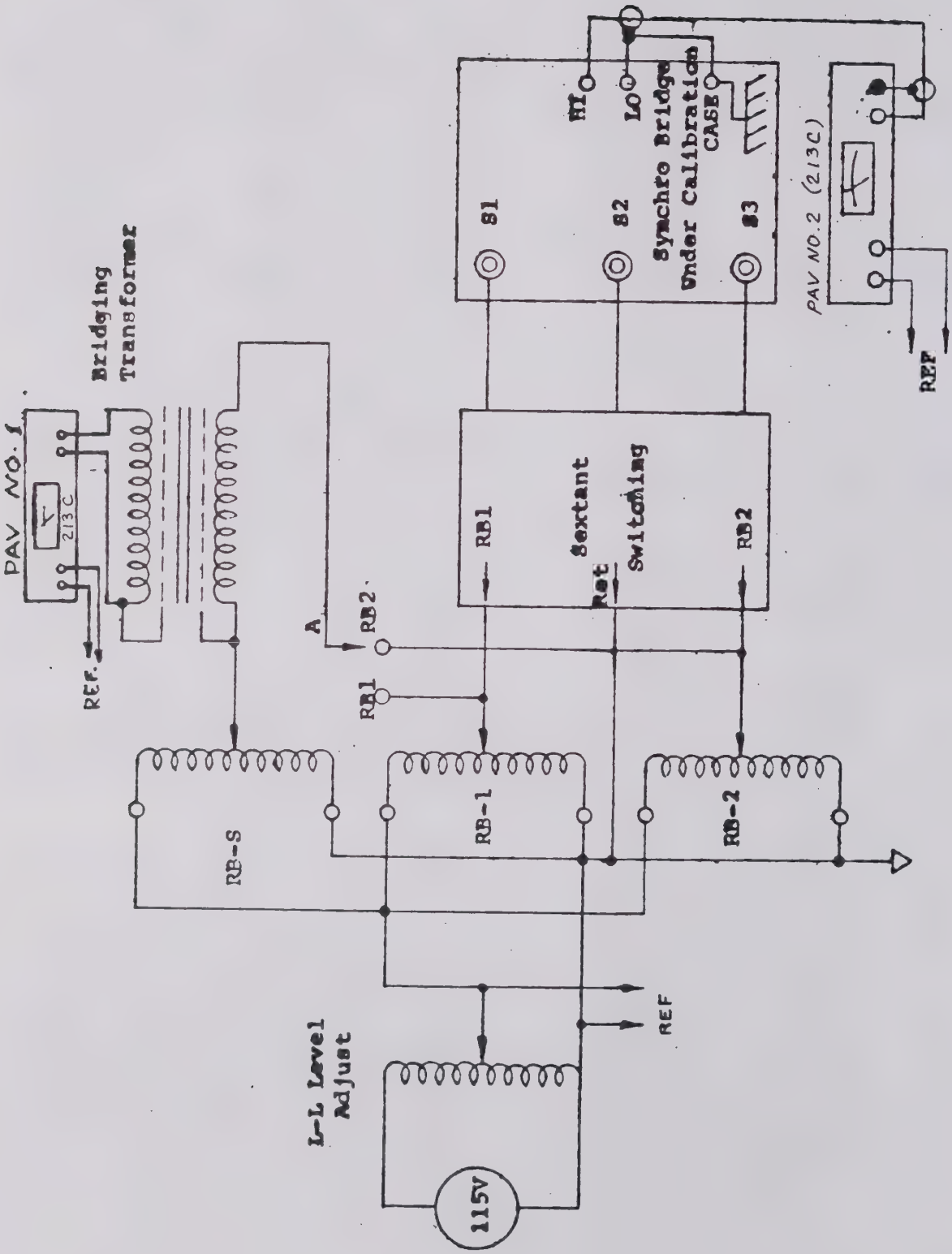

Figure 6-4. Synchro Bridge Calibration Hookup

To correct for this loading error, the 1.0 ppm ratio box designated RS-S is used as a precision ratio transfer device by which the proper voltage ratios can be set up on RB-1 and RB-2 while under load. The bridge null transformer and phase angle voltmeter No. 1, are used to make the comparison between the ratio reference RB-S and driving ratio boxes RB-1 and RB-2.

a. Adjust Variac T-1, or variable source for desired line-to-line voltage (90, 11.8, etc.) to accuracy of ±5%.

b. Adjust phase angle voltmeter No. 1 for an in-phase null (0°).

c. With synchro bridge under test set at the angle being calibrated, set RB-S to desired setting of RB-2 obtained from tables 6-7 through 6-12.

d. Connect null transformer lead A to the output of RB-2 and adjust for a null on phase angle voltmeter No. 1 set to a resolution of at least 1/3 ppm.

e. Repeat steps c and d for setting on RB-1.

f. Input to bridge is now accurate to within 0.2 seconds. Now adjust bridge to achieve in-phase null on phase angle voltmeter No. 2. Read and record calibration angle from bridge.

g. Repeat steps c through f for each angle to be calibrated. Note that tables 6-7 through 6-12 are given for the most commonly tested angles.

6.5.4.4 Simulator Calibration

6.5.4.4.1 Equipment Required

The following test equipment is required to calibrate the simulator.

Qty	Equipment
1	Phase Angle Voltmeter, North Atlantic Model 213C, 321, or 225
1	Calibrated Bridge, North Atlantic Model 540
1	Adjustable 400 Hz ac voltage source

Table 6-7. Synchro Calibration - 0° to 360° (5° Increments)

I	II	III	IV	V	VI	RB1	RB2
0°	120°	120°	240°	240°	360°	.8660254	.000000
5°	115°	125°	235°	245°	355°	.9063077	.0871557
10°	110°	130°	230°	250°	350°	.9396926	.1736480
15°	105°	135°	225°	255°	345°	.9659258	.2588190
20°	100°	140°	220°	260°	340°	.9848077	.3420201
25°	95°	145°	215°	265°	335°	.9961946	.4226182
30°	90°	150°	210°	270°	330°	1.0000000	.5000000
35°	85°	155°	205°	275°	325°	.9961946	.5735764
40°	80°	160°	200°	280°	320°	.9848077	.6427876
45°	75°	165°	195°	285°	315°	.9659258	.7071067
50°	70°	170°	190°	290°	310°	.9396926	.766044
55°	65°	175°	185°	295°	305°	.9063077	.8191520
60°	60°	180°	180°	300°	300°	.8660254	.8660254

Table 6-8. Synchro Calibration– 40° to 49° (1° Increments)

Angle	RB1 (Cos)	RB2 (Sin)
40°	.9848077	.6427876
41°	.9816272	.6560590
42°	.9781476	.6691306
43°	.9743701	.6819984
44°	.9702957	.6946584
45°	.9659258	.7071067
46°	.9612617	.7193398
47°	.9563048	.7313537
48°	.9510565	.7431448
49°	.9455186	.7547096

Table 6-9. Synchro Calibration– 40.1° to 40.9° (0.1° Increments)

Angle	RB1 (Cos)	RB2 (Sin)
40.1°	.9845032	.6441236
40.2°	.9841956	.6454577
40.3°	.9838850	.6467898
40.4°	.9835715	.6481199
40.5°	.9832549	.6494480
40.6	.9829353	.6507742
40.7°	.9826128	.6520984
40.8°	.9822873	.6534206
40.9°	.9819587	.6547408

Table 6-10. Synchro Calibration– 40.01° to 40.09° (0.01° Increments)

Angle	RB1 (Cos)	RB2 (Sin)
40.01°	.9847774	.6429213
40.02°	.9847471	.6430550
40.03°	.9847167	.6431886
40.04°	.9846863	.6433223
40.05°	.9846558	.6434559
40.06°	.9846254	.6435895
40.07°	.9845949	.6437230
40.08°	.9845643	.6438566
40.09°	.9845338	.6439901

Table 6-11. Synchro Calibration– 40.001° to 40.009° (0.001° Increments)

Angle	RB1 (Cos)	RB2 (Sin)
40.001°	.9848047	.6428010
40.002°	.9848016	.6428143
40.003°	.9847986	.6428277
40.004°	.9847956	.6428411
40.005°	.9847926	.6428545
40.006°	.9847895	.6428678
40.007°	.9847865	.6428812
40.008°	.9847835	.6428946
40.009°	.9847804	.6429073

Table 6-12. Synchro Calibration Sextant Switching

Sextant	Angle	RB1 Hi	Ret	RB2 Lo
I	0-60°	S2	S1	S3
II	60-120°	S3	S1	S2
III	120-180°	S3	S2	S1
IV	180-240°	S1	S2	S3
V	240-300°	S1	S3	S2
VI	300-360°	S2	S3	S1

6.5.4.4.2 Procedure

Connect equipment as shown in figure 6-2. The technique used in calibrating the simulator consists of comparing the simulator under test with a bridge calibrated in accordance with the methods previously outlined.

The technique is identical to that described in paragraph 6.5.3. Comparison can be made by the deviation method or by nulling using either the calibrated bridge or the simulator under test. The calibration error, of course, would be combining the calibration data for the bridge plus the deviation of the bridge and simulator, as measured in this procedure.

SECTION 7

ROTARY COMPONENT MEASUREMENT

7.1 GENERAL

This section provides a detailed step-by-step procedure for precise test of the most commonly encountered types of synchros and resolvers using North Atlantic Model 530 Resolver-Synchro Simulator and Model 540 Resolver-Synchro Bridge.

7.2 SYNCHRO TRANSMITTER (CX) TEST

7.2.1 Phasing, Electrical Zero, and Angular Accuracy

a. Connect equipment as shown in figure 7-1. Rotate CX shaft counterclockwise as viewed from shaft end until phase angle voltmeter (PAV) reads zero. Note that the meter approaches 0 from left to right. For 115 V excitation, use 100 V range of the PAV.

b. With synchro shaft at the null point, switch Model 540 to 5°. The PAV should deflect to the left. Set Model 540 back to 0.

c. If the requirements of steps a and b are met, the phase is correct, and the null point is electrical zero.

d. Mount CX in a dividing head.

e. With the dividing head at 0°, CX must be at electrical zero, as described in steps a and b.

f. Set PAV Function selector to 90°.

g. Set Model 540 to 90°.

h. Rotate Phase dial on the PAV until a quadrature null is reached.

i. The angle read on the Phase Angle dial is approximately equal to the phase shift of the CX.

j. With the Phase dial at this setting, return Model 540 and the Function selector to 0°.

k. Re-zero CX in dividing head if necessary.

l. With the CX at 0°, offset the dividing head an amount equal to the maximum allowable error of the CX.

m. Down scale the Range selector until the first off-scale meter reading is reached. Turn the Range selector to the next up-scale range. Record the deflection on the PAV. This is the maximum allowable error voltage.

n. Return the dividing head to 0°.

o. Advance the Model 540 and the dividing head in the required increments. The null error, as noted on the PAV, should be less than that obtained in step m.

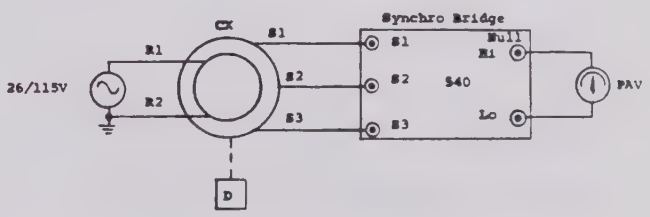

Figure 7-1. Angular Accuracy (CX)

7.2.2 Null Test, Total and Fundamental

a. With the CX still mounted in the dividing head, set up equipment shown in figure 7-2.

b. Rotate dividing head to 120°.

c. Set the PAV Function selector to 0°, and adjust the dividing head for a null.

d. Read the nulls in both Total and Fundamental modes.

e. Attach PAV leads to S2 and S3 of the CX, and rotate the dividing head to 240°.

f. Repeat steps c and d.

g. Attach PAV leads to S1 and S3 of the CX, and rotate the dividing head to 0°.

h. Repeat steps c and d.

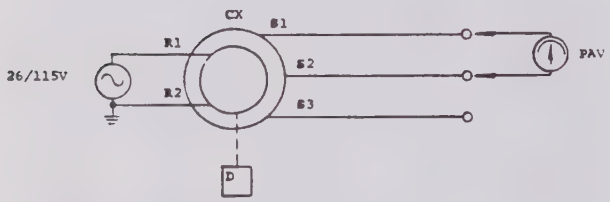

Figure 7-2. Null Test (CX)

7.2.3 Transformation Ratio Test

a. Turn Phase Angle dial to 0°.

b. With the CX still mounted in a dividing head, set up equipment as shown in figure 7-3.

c. Set Function selector to 0°.

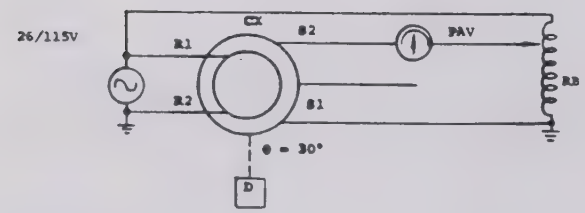

Figure 7-3. Transformation Ratio Test (CX)

d. Set the dividing head to 30°, and adjust ratio box for a null. Record ratio reading (transformation ratio).

7.2.4 Phase Shift Test

a. With the CX still mounted in the dividing head, set up equipment as shown in figure 7-4.

b. Set PAV Function selector to 90° position.

c. With dividing head at 30°, adjust the Phase Angle dial on the PAV for a quadrature null.

d. The phase shift of the CX may be read directly from the Phase Angle dial.

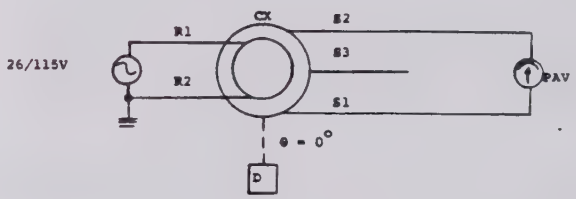

Figure 7-4. Phase Shift Test (CX)

7.2.5 Input Current Test

a. Set up equipment as shown in figure 7-5.

b. Turn PAV Function selector to the Total position.

c. The input current of the CX is read directly in amperes on the PAV, i.e., 0.1 volt = 0.1 amperes.

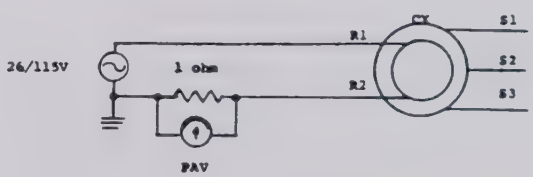

Figure 7-5. Input Current Test (CX)

7.3 SYNCHRO DIFFERENTIAL TRANSMITTER (CDX) TEST

7.3.1 Phasing, Electrical Zero, and Angular Accuracy Test

a. Set up equipment as shown in figure 7-6.

b. Set Models 530 and 540 to 0°.

c. Rotate CDX shaft counterclockwise, as viewed from the shaft end, until the meter reads zero. Note that the needle approaches zero from left to right. For 115 V excitation, use 30 V range of the PAV.

d. With synchro shaft at null, set the Model 540 to 5°. The PAV should deflect to the left. Return to 0°.

e. Set Model 530 to 5°. The PAV should deflect to the left. Return the Model 530 to 0°.

f. If the requirements of steps c, d, and e are met, the phasing is correct, and the null point is electrical zero.

g. Mount CDX in the dividing head.

h. With the dividing head at 0°, CDX must be at electrical zero, as defined by steps c through e.

i. Set PAV Function selector to 90°.

j. Set Model 540 to 90°.

k. Rotate the Phase Angle dial until quadrature null is reached.

l. The angle read on the Phase Angle dial is approximately equal to the phase shift of the CDX.

m. With the Phase Angle dial left at this setting, return the Model 540 and the Function selector to 0°.

n. Re-zero CDX in the dividing head if necessary.

o. With the CDX at zero, offset dividing head by an amount equal to the maximum allowable error of the CDX.

p. Down scale the Range selector until the first off scale meter reading is reached. Turn the Range selector to the next upscale range. Record the deflection noted on the PAV. This is the maximum allowable error voltage.

q. Return dividing head to 0°.

r. Advance the Model 530 and the dividing head in the required increments. The null as noted on the PAV should be less than that obtained in step p.

s. Set up equipment as shown in figure 7-7, with CDX still mounted in the dividing head.

t. Check that CDX is zero and dividing head is set to zero.

u. Advance the Model 530 and the dividing head in the required increments. The null error as noted on the PAV should be less than that obtained in step p.

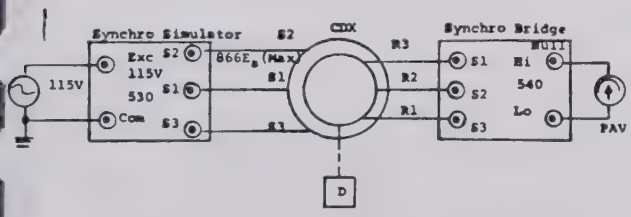

Figure 7-6. Angular Accuracy (Rotor) (CDX)

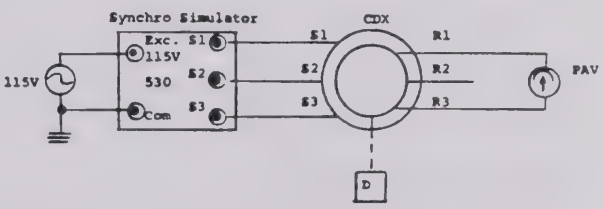

Figure 7-7. Angular Accuracy (Stator) (CDX)

7.3.2 Null Test, Fundamental and Total

a. Set up equipment as shown in figure 7-8.

b. Attach PAV leads to R1 and R2.

c. Set Model 530 to 120° and dividing head to 0°.

d. Set PAV Function selector to 0° and adjust dividing head vernier for a null.

e. In the Total and Fundamental positions of the Function selector, read the respective nulls.

f. Set Model 530 to 240° and dividing head to 120°.

g. Repeat steps d and e.

h. Set Model 530 to 0° and dividing head to 240°.

i. Repeat steps d and e.

j. Attach PAV leads to R2 and R3.

k. Set Model 530 to 240° and dividing head to 0°.

l. Repeat steps d and e.

m. Set Model 530 to 0° and dividing head to 120°.

n. Repeat steps d and e.

o. Set Model 530 to 120° and dividing head to 240°.

p. Repeat steps d and e.

q. Attach PAV leads to R1 and R3.

r. Set Model 530 to 120° and dividing head to 0°.

s. Repeat steps d and e.

t. Set Model 530 and dividing head to 120°, and repeat steps d and e.

u. Set Model 530 and dividing head to 240°, and repeat steps d and e.

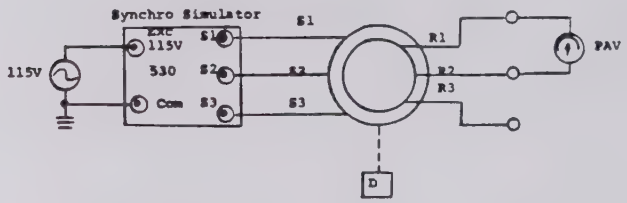

Figure 7-8. Null Test (CDX)

7.3.3 Transformation Ratio Test

a. Set up equipment as shown in figure 7-9

b. Set Phase Angle dial to 0°.

c. Set dividing head to 30°.

d. Switch PAV Function selector to 0°.

e. Set ratio box for a null on the PAV.

f. Record ratio reading.

g. Transformation ratio is obtained by dividing in-phase ratio by cos 30° (.866).

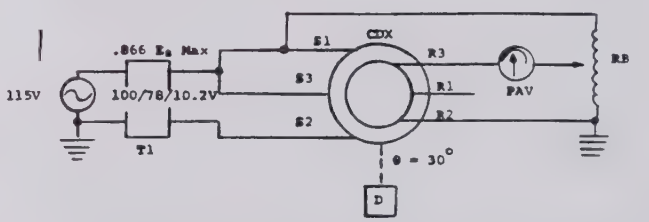

Figure 7-9. Transformation Ratio Test (CDX)

7.3.4 Phase Shift Test

a. Set up equipment as shown in figure 7-10.

b. Set Function selector to 90°.

c. Set dividing head to 30° and rotate Phase Angle dial for quadrature null.

d. The phase shift of the CDX may be read directly from the Phase Angle dial.

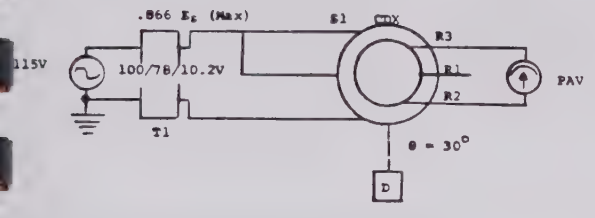

Figure 7-10. Phase Shift Test (CDX)

7.3.5 Input Current Test

a. Set up equipment as shown in figure 7-11.

b. Set PAV Function selector to Total.

c. The input current of the CDX is read directly in amperes on the PAV, i.e., 0.1 V = 0.1 A.

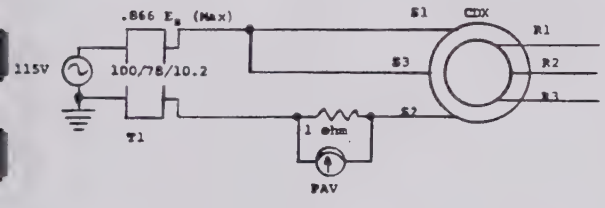

Figure 7-11. Input Current Test (CDX)

7.4 SYNCHRO TRANSFORMER (CT) TEST

7.4.1 Phasing, Electrical Zero, and Angular Accuracy

a. Set up equipment as shown in figure 7-12.

b. Set Model 530 to 0°.

c. Rotate CR shaft counterclockwise, as viewed from the shaft end, until the meter reads zero. Note that the needle approaches zero from left to right. For 115 V or 90 V excitation, use the 100 V range of the PAV. For 11.8 V excitation, use the 10 V range of the PAV.

d. With synchro shaft at the null point, switch Model 530 to 5°. The PAV should deflect to the left.

e. Return the Model 530 to 0°.

f. If requirements of steps c and d are met, the phasing is correct, and the null point is electrical zero.

g. Mount CT in the dividing head.

h. With the dividing head at 0°, CT must be at electrical zero, as defined in steps c and d.

i. Set PAV Function selector to 90°.

j. Set Model 530 to 90°.

k. Rotate the Phase Angle dial until quadrature null is reached.

l. With Phase Angle dial left at this setting, return the Model 530 to 0°, and set the Function selector to 0°.

m. Re-zero CT in the dividing head if necessary.

n. With CT at zero, offset dividing head by an amount equal to the maximum allowable error of the CT.

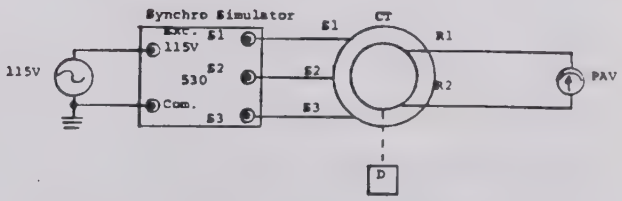

Figure 7-12. Angular Accuracy (CT)

o. Down-scale the Range selector until the off-scale meter reading is reached.

Turn the Range selector to the next up-scale range. Record the deflection noted on the PAV. This is the maximum allowable error voltage.

p. Return the dividing head to 0°.

q. Advance the Model 530 and the dividing head in required increments. The null error as noted on the PAV should be less than that obtained in step o.

7.4.2 Null Test, Fundamental and Total

a. Set up equipment as shown in figure 7-13.

b. Set Model 530 and dividing head to 0°.

c. Set the PAV Function selector to 0° and adjust dividing head vernier for a null.

d. Read the null in the Total and Fundamental position of the Function selector.

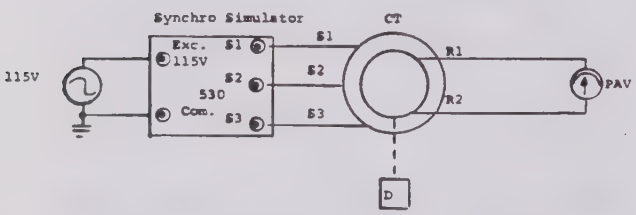

Figure 7-13. Null Test (CT)

7.4.3 Transformation Ratio Test

a. Set up equipment as shown in figure 7-14.

b. Turn Phase Angle dial to 0°.

c. Set dividing head to 270°.

d. Set PAV Function selector to 0°.

e. Adjust ratio box for a null on the meter.

f. Record ratio box reading.

g. Transformation ratio is obtained by dividing in-phase ratio by cos 30° (.866)

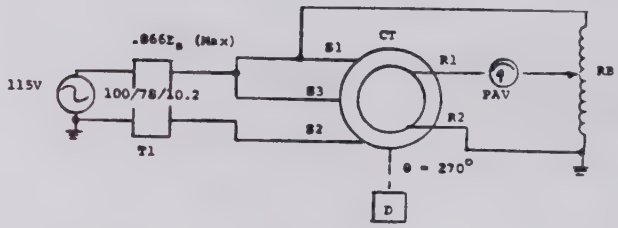

Figure 7-14. Transformation Ratio Test (CT

7.4.4 Phase Shift Test

a. Set up equipment as shown in figure 7-15.

b. Set PAV Function selector to 90°.

c. With dividing head at 270°, rotate Phase Angle dial on the PAV for a null.

d. The phase shift of the CT may be read directly from the Phase Angle dial.

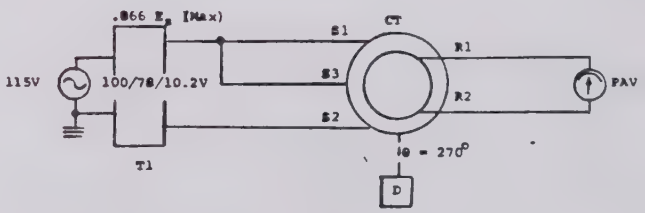

Figure 7-15. Phase Shift Test (CT)

7.4.5 Input Current Test

a. Set up equipment as shown in figure 7-16.

b. Set PAV Function selector to Total.

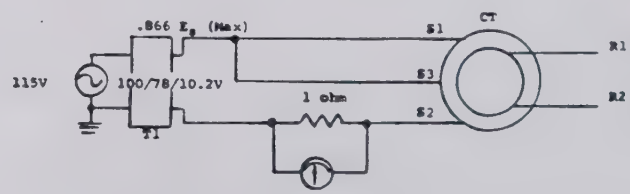

Figure 7-16. Input Current Test (CT)

c. The input current of the CT is read directly in amperes on the voltmeter, i.e., .1 V = .1 A.

7.5 RESOLVER TRANSMITTER (RX)

7.5.1 Phasing, Electrical Zero, and Angular Accuracy

a. Set up equipment as shown in figure 7-17.

b. Set Model 540 to 0°.

c. Rotate RX shaft counterclockwise, as viewed from the shaft end, until meter reads zero. Note that the needle approaches zero from right to left.

d. For 115 V excitation, use 100 V range of the PAV. For 26 V excitation, use 30 V range of the PAV.

e. With resolver shaft at the null point, switch Model 540 to 5°.

f. Return the Model 530 to 0°.

g. If the requirements of steps c and e are met, the phasing is correct, and the null point is electrical zero.

h. Mount RX in a dividing head.

i. With the dividing head at 0°, RX must be at electrical zero as described in steps c and e.

j. Set PAV Function selector to 90°.

k. Set Model 540 to 90°.

l. Rotate Phase Angle dial until quadrature null is reached.

m. The angle read on the Phase Angle dial is approximately equal to the phase shift of the RX.

n. With the Phase Angle dial left at this setting, return the Model 540 and the Function selector to 0°.

o. Re-zero the CX and the dividing head if necessary.

p. With RX at zero, offset the dividing head by the maximum allowable error.

q. Down-scale the Range selector until the first off-scale meter reading is reached. Turn the Range selector to the next up-scale range. Record the deflection noted on the PAV. This is the maximum allowable error voltage.

r. Return the dividing head to 0°.

s. Advance Model 540 and the dividing head in required increments. The null error as noted on the PAV should be less than that obtained in step q.

7.5.2 Null Test, Fundamental and Total

a. Set up equipment as shown in figure 7-18.

b. Set dividing head to 0°.

c. Set Function selector to 0°, and adjust dividing head vernier for a null.

d. Read null in Total and Fundamental positions of the Function selector.

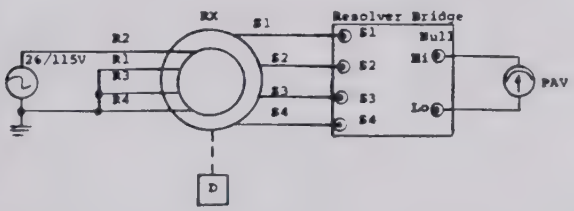

Figure 7-17. Angular Accuracy Test (RX)

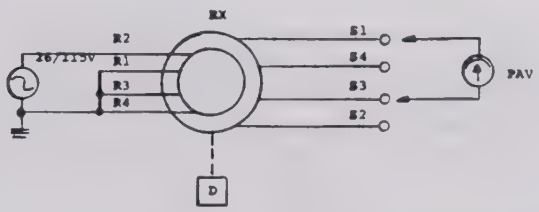

Figure 7-18. Null Test (RX)

e. Connect PAV leads to S2 snd S4 and rotate dividing head to 90°.

f. Repeat steps c and d, above.

7.5.3 Transformation Ratio Test

a. Set up equipment as shown in figure 7-19.

b. Set PAV Phase Angle dial to 0°.

c. Set PAV Function selector to 0°.

d. Set dividing head to 0°, and adjust ratio box for a null.

e. Record ratio reading (transformation ratio).

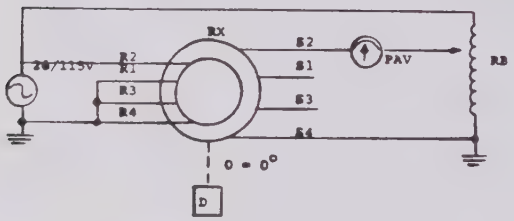

Figure 7-19. Transformation Ratio Test (RX)

7.5.4 Input Current

a. Set up equipment as shown in figure 7-20.

b. Set PAV Function selector to Total.

c. The input current of the RX is read directly in amperes on the voltmeter, i.e., .1 V = .1 A.

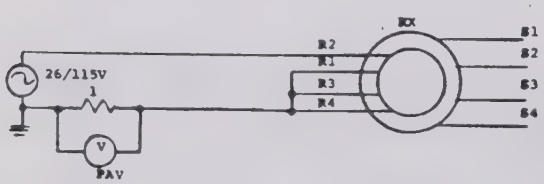

Figure 7-20. Input Current Test (RX)

7.5.5 Phase Shift Test

a. Set up equipment as shown in figure 7-21.

b. Set Function selector to 90°.

c. With the dividing head at 0°, rotate the Phase Angle dial on the PAV for a null.

d. The phase shift of the RX may be read directly from the Phase Angle dial.

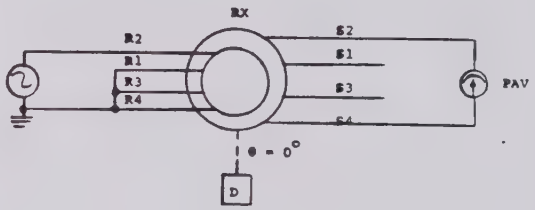

Figure 7-21. Phase Shift Test (RX)

7.6 DIFFERENTIAL RESOLVER AND TRANSFORMER (RD/RC) TESTS

7.6.1 Phasing, Electrical Zero, and Angular Accuracy

a. Set up equipment as shown in figure 7-22.

b. Set Models 530 and 540 to 0°.

c. Turn control panel power on, and rotate RD/RC shaft counterclockwise as viewed from the shaft end until the meter reads 0°. Note that the needle

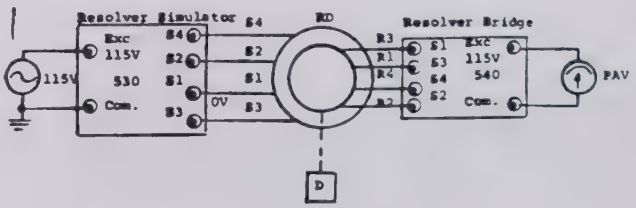

Figure 7-22. Angular Accuracy (RD Rotor)

approaches zero from left to right. For 115 V excitation, use 100 V range of the PAV. For 11.8 V excitation, use 10 V range of the PAV.

d. With RD/RC shaft at null point, set Model 540 to 5°.

e. The PAV should deflect to the left. Return Model 540 to 0°.

f. Set Model 530 to 5°. The meter should deflect to the left.

g. Return Model 530 to 0°.

h. If requirements of steps c through f are met, phasing is correct, and the null point is electrical zero.

i. Mount RD/RC in a dividing head.

j. With the dividing head at 0°, RD/RC must be at electrical zero as described in steps c through f.

k. Set Model 530 to 90°.

l. Set PAV Function selector to 90°.

m. Rotate Phase Angle dial until quadrature null is reached.

n. The angle read on the Phase Angle dial is approximately equal to the phase shift of the RD/RC.

o. Re-zero RD/RC in the dividing head if necessary.

p. With RD/RC at zero, offset the dividing head by an amount equal to the maximum allowable error of the RD/RC.

q. Down scale the Range selector until the first off-scale meter reading is reached. Turn the Range selector to the next up-scale range. Record the deflection noted on the PAV. This is the maximum allowable error voltage.

r. Return the dividing head to 0°.

s. Advance Model 540 and the dividing head in required increments. The null error as noted on the PAV should be less than that obtained in step q.

t. Set up equipment as shown in figure 7-23.

u. Re-zero RD in the dividing head if necessary.

v. Advance Model 530 and the dividing head in the required increments. The null error as noted on the PAV should be less than that obtained in step q.

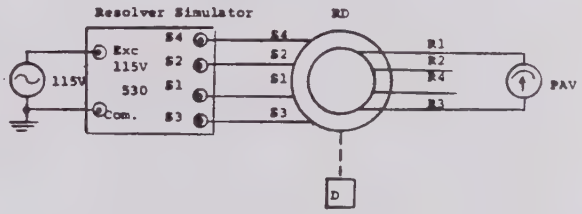

Figure 7-23. Angular Accuracy (RD and RC Stator)

7.6.2 Null Test, Fundamental and Total

a. Set up equipment as shown in figure 7-24.

b. Set Model 530 and dividing head to 0°.

c. Set Function selector to 0°, and adjust the dividing head vernier for a null.

d. Read the null in both Total and Fundamental positions of the Function selector.

e. Set Model 530 and dividing head to 90°.

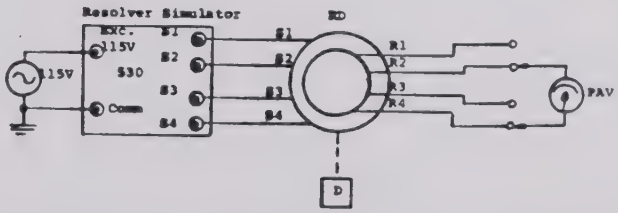

Figure 7-24. Null Test (RD/RC)

f. Repeat steps c and d.

g. Connect PAV leads to R2 and R4.

h. Set Model 530 to 90° and dividing head to 0°.

i. Repeat steps c and d.

j. Set Model 530 to 0° and dividing head to 90°.

k. Repeat steps c and d.

7.6.3 Transformation Ratio Test

a. Set up equipment as shown in figure 7-25.

b. Turn Phase Angle dial to 0°.

c. Turn PAV Function selector to 0°.

d. Set dividing head to 0°.

e. Adjust ratio box for a null on the PAV.

f. Record ratio box reading (transformation ratio).

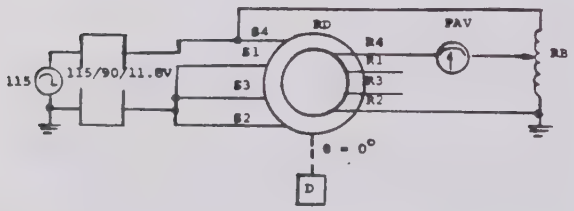

Figure 7-25. Transformation Ratio Test (RD/RC)

7.6.4 Phase Shift Test

a. Set up equipment as shown in figure 7-26.

b. Set PAV Function selector to 90°.

c. With the dividing head at 0°, rotate the Phase Angle dial on the PAV for a null.

d. The phase shift of the RD/RC may be read directly from the Phase Angle dia

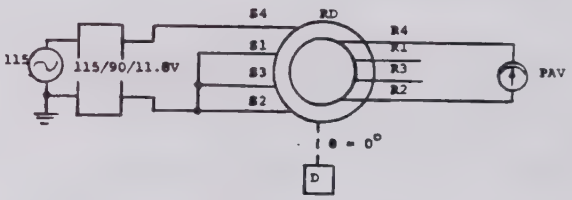

Figure 7-26. Phase Shift Test (RD/RC)

7.6.5 Input Current Test

a. Set up equipment as shown in figure 7-27.

b. Set PAV Function selector to Total.

c. The input current of the RD/RC is read directly in amperes on the PAV, i.e., .1 V = .1 A.

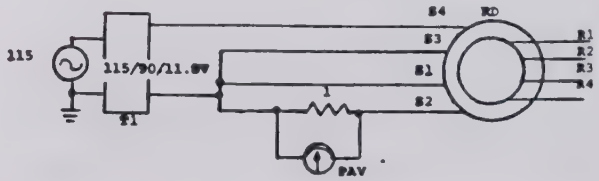

Figure 7-27. Input Current Test (RD/RC)

SECTION 8

REPLACEMENT PARTS LIST AND SCHEMATIC

This section contains a vendor codes list, parts list, and a schematic for the Model 530 Resolver-Synchro Simulator.

LIST OF MANUFACTURERS

Code	Name and address
07342	North Atlantic Industries, Inc. 60 Plant Avenue Hauppauge, New York 11788
71400	Buss Manufacturing Div. of McGraw Edison University at Jefferson Street St. Louis, Missouri 63107
71785	Cinch Manufacturing Co., Inc. 1026 South Homan Avenue Chicago, Illinois 60624
75915	Littlefuse, Inc. 800 E.N.W. Highway Des Plaines, Illinois 60016
81073	Grayhill Inc. 561 Hillgrove Avenue LaGrange, Illinois 60525
83330	H.H. Smith 812 Snediker Avenue Brooklyn, New York 11207

Replacement Parts List: Resolver-Synchro Simulator, Model 530, .0001°

Ref. Des.	Description	NAI Part No.	Mfr. Code	Mfr. Part No.	Total Qty
F1, F3	Fuse, 1 A (Slo-Blo)	803876	75915	313001.	2
F2	Fuse, 2 A (Slo-Blo)	800935	71400	MDL	1
	Fuseholder	800117	75915	342001L	
	Knob, Fuseholder	802535	71400	AF KNOB	
	Binding Post, Black Front Panel (Return)	800120	81073	29-1B	
	Binding Post, Red Front Panel	800119	81073	29-1R	
	Binding Post, Ground	800546	83330	137	
	Terminal Strip, Rear Panel (3 contact)	800895	71785	321-11-03-011	
	Terminal Strip, Rear Panel (4 contact)	801652	71785	321-11-04-005	
S1	Switch Assembly, 1°	782163			
S2	Switch Assembly, .1°	782164			
S3	Switch Assembly, .01°	782173			
S4,S5	Switch, Concentric Shaft, .0001°	202263			
S6,S7	Switch, Concentric (Mode)	201965			
S18	Switch Assembly, 10°	782159			
	Knob, Concentric, Inside	201720-1			
	Knob, Concentric, Outside	202158			
	Knob, Concentric, Outside	201719-1			
	Knob, Concentric, Outside	201946-1			
	Knob	201979			
	Dial Assembly, 100°	500395-1			
	Dial, 10°	201955			
	Dial Assembly, 1°, .1°, .01°	500395-2			
	Dial Assembly	500395-3			
T1	Transformer Can Assembly (A)	782259			
T2	Transformer Can Assembly (B)	782262			

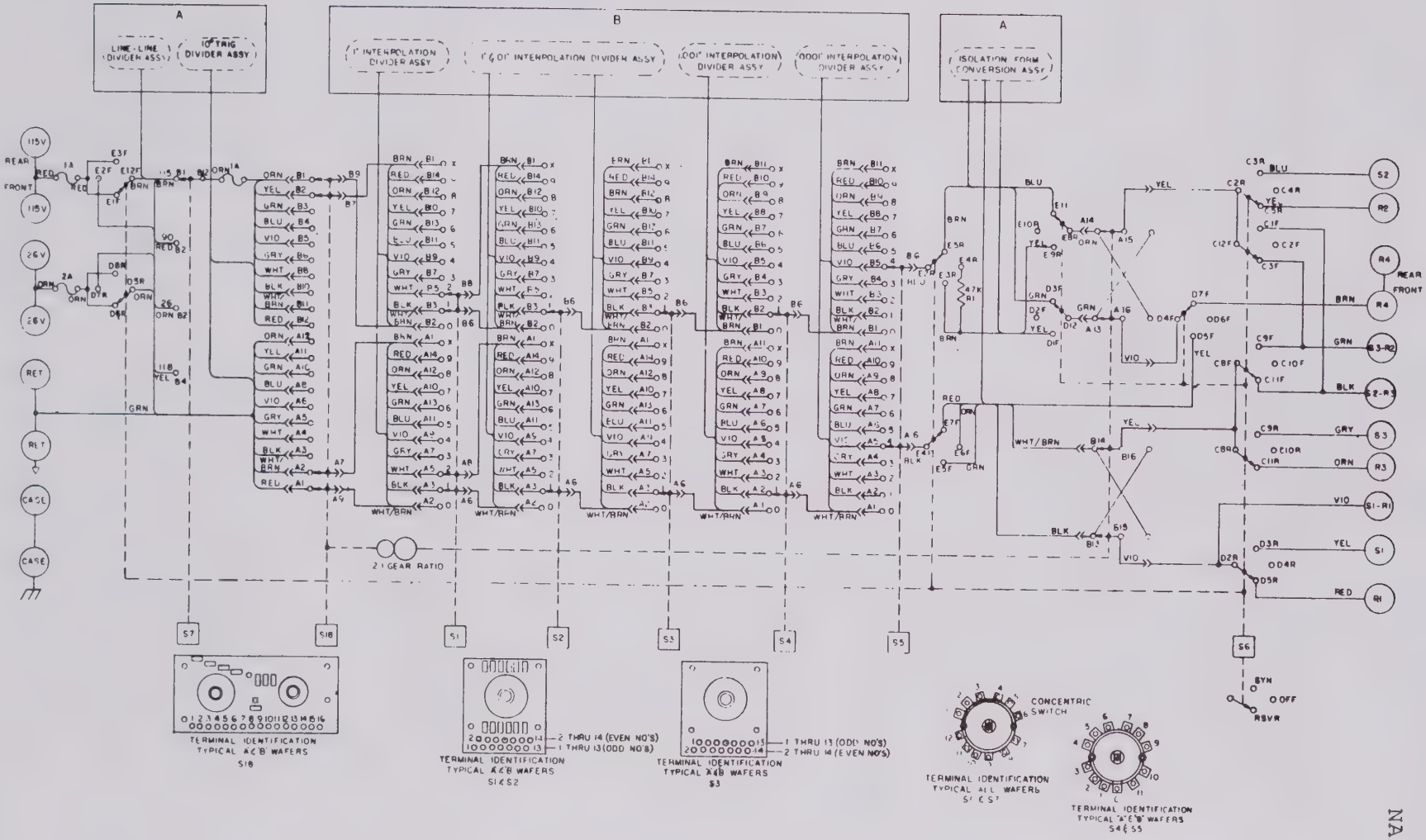

Figure 8-1. Model 530, System Schematic

WARRANTY

A. The Seller warrants Products against defects in material and workmanship for one year from the date of original shipment. The Seller's liability is limited to the repair or replacement of Products which prove to be defective during the Warranty period. There is no charge under the Warranty except for transportation charges. The Purchaser shall be responsible for Products shipped until received by the Seller.

B. The Seller specifically excludes from the Warranty 1) calibration, 2) fuses, and 3) normal mechanical wear, e.g.; end-of-life on assemblies such as switches, relays, gear trains, etc. is dependent upon number of operations or hours of use, and end-of-life may occur within the Warranty period.

C. The Seller is not liable for consequential damages or for any injury or damage to persons or property resulting from the operation or application of Products.

D. The Warranty is voided if there is evidence that Products have been operated beyond their design range, improperly installed, improperly maintained or physically mistreated.

E. The Seller reserves the right to make changes and improvements to Products without any liability for incorporating such changes or improvements in any Products previously sold, or for any notification to the Purchaser prior to shipment. In the event the Purchaser should require subsequently manufactured lots to be identical to those covered by this Quotation, the Seller will, upon written request, provide a quotation upon a change control program.

F. No other Warranty expressed or implied is offered by the Seller other than the foregoing.

CLAIMS FOR DAMAGE IN SHIPMENT

The purchaser should inspect and functionally test the Product(s) in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or if insured separately, with the purchaser's insurance company.

SHIPPING

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in a sealed plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

WARRANTY REGISTRATION

Please complete and mail this Warranty Registration Card without delay. Placing this Registration on file with our Service Department will assure that you receive applicable service data as issued. No postage is required.
(Mailed on_____ by_____)

WARRANTY REGISTRATION

Date _____

Please register _____
Model No. _____ Serial No. _____
under the terms of the warranty stated in this Instruction Manual.
Name _____
Title _____ Dept. _____
Company _____
Address _____
City _____ State _____ ZIP _____
Calibration and maintenance responsibility has been assigned to the following person and/or department. Address applicable service data to (if same as above, please state):
Name _____
Title _____ Dept. _____
For our information please indicate:
Condition of instrument on receipt _____
Application _____
Will the instrument be: resold as part of a system? _____
maintained as company equipment? _____

SERVICE INFORMATION

This card is provided to aid you in obtaining prompt assistance with questions you may have regarding operation, calibration, maintenance or service parts for your North Atlantic instrument. State information desired and mail. No postage is required.

SERVICE INFORMATION REQUEST

Instrument _____
Model No. _____ Serial No. _____
We require the following service information: _____
_____
_____
_____
_____
Name _____ Title _____
Company _____ Dept. _____
Address _____
City _____ State _____ ZIP _____
Phone _____ Ext. _____

SERVICE INFORMATION

This card is provided to aid you in obtaining prompt assistance with questions you may have regarding operation, calibration, maintenance or service parts for your North Atlantic instrument. State information desired and mail. No postage is required.

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We require the following service information: _____
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Name _____ Title _____
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Address _____
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Phone _____ Ext. _____
(please send additional Service Information Request cards.)

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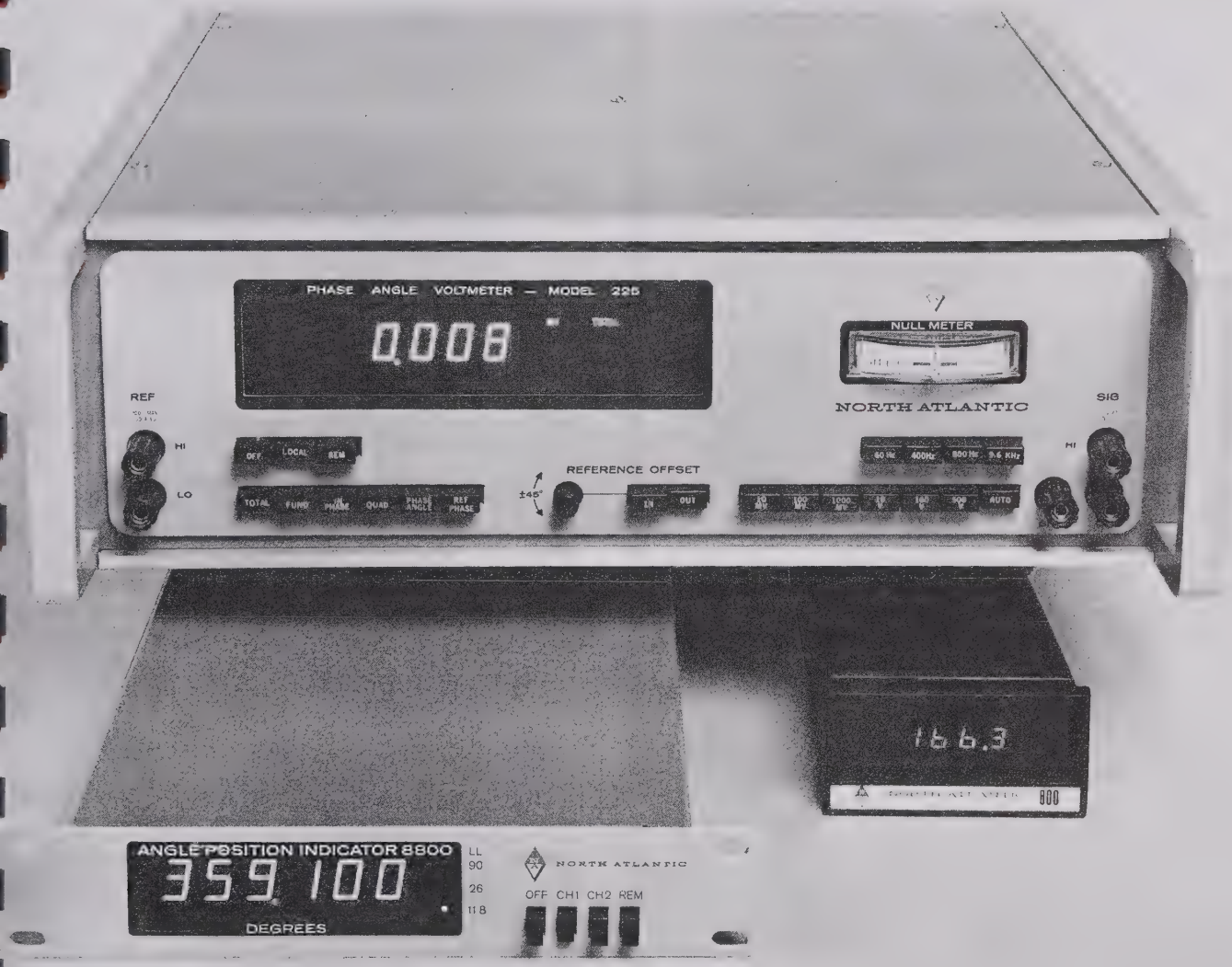


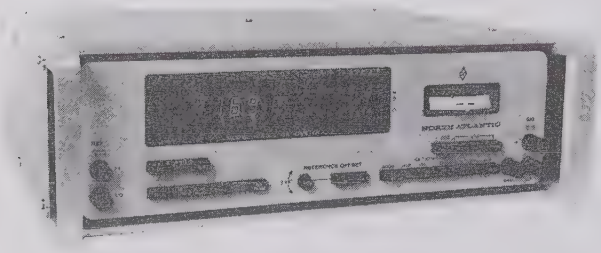
AC and Synchro Instrumentation

NORTH ATLANTIC Industries

60 Plant Avenue,
Hauppauge, NY 11788
(516) 582-6500
(800) 645-5292
TWX 510-227-9660
Cable: NO ATLANTIC

DIGITAL PHASE ANGLE VOLTMETERS

This series of instruments provides the digital equivalent of the well-known Phase Angle Voltmeter, but with significant increases in both precision and speed of measurement. Voltage measurements include total, fundamental, in-phase, and quadrature. Phase measurements are from 0° to 359.9°, and a +45° reference offset control is provided. Full-scale voltage ranges (10mV to 1000mV) and phase angle (359.9°) are directly read on a 4-½ digit display. Voltage ranges may be pushbutton selected or auto-ranged. All models provide for both manual and remote programming or optional 488 IB (IEEE-STD-488-1975) interface bus. Digital outputs include reading, mode, range and polarity information as well as data status signals. Long-term use of this instrument series is assured since field-change of frequency plug-in modules requires only a routine recalibration procedure.



Model 225
Digital Phase Angle Voltmeter

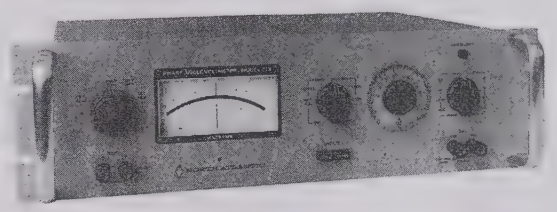
Designed for multi-frequency applications, the Model 225 is available with 1, 2, 3, or 4 pre-specified plug-in frequency modules (30Hz to 54KHz). They feature pushbutton selection of Voltage range (or auto-range), measurement mode and frequency range. Voltage accuracy is 0.05% and phase accuracy is 0.2°. Local/remote pushbutton selection permits remote programming of all functions for ATE use. Broadband signal isolation features 10M input impedance. A standard null meter is included for applications such as synchro nulling (full-scale adjust is an option).

Model 225/Ratiometer
Digital Phase Angle Voltmeter

Incorporating all of the 225 features (and options), an added ratiometric mode provides direct reading ratio ranges from .0002 to 20.00. Signal input voltages (numerator) from 1mV to 500V, and reference voltages (denominator) from 3V to 126V are accommodated. No adjustments are required, only selection of the proper signal range Accuracy is a function of reading, range, and reference level, and accuracies to .2% are achievable.

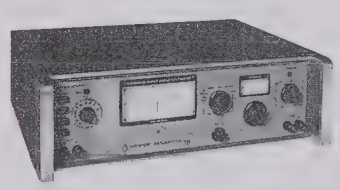
PHASE ANGLE VOLTMETER

These multifunctional instruments combine phase-sensitive modes with the functions of a conventional AC voltmeter operating over the range of 10Hz to 100KHz. They provide direct-reading voltage measurement of the total, fundamental, in-phase and quadrature components of an AC signal to 2% full-scale, as well as phase angle to 1°.They feature calibrated voltage ranges of 300*u*V (or 1mV) to 300V rms full-scale, built-in or plug-in harmonic-rejection filters, high quadrature overload capability, and operation with a wide range of reference voltages.



Model 213C Phase Angle Voltmeters

This solid-state instrument, successor to the famous VM-202, provides phase-sensitive measurement at a single pre-specified frequency from 30Hz to 10KHz with +5% frequency bandwidth (without adjustment). Full-scale measurement from 300*u*V to 300V. The Model 213C has signal and reference isolation.



Model 321
Broadband Phase
Angle Voltmeter

The Model 321 combines in one instrument, a phase sensitive null detector, a phase sensitive voltmeter and a phase meter, operating over the frequency range of 10Hz to 100KHz. It's broadband characteristics make it ideally suited for use in amplifier and network design, vibration analysis, telemetry system measurements, biomedical research, and similar applications requiring the measurement of complex signals and their vector components over a broad range of frequencies

The model 321 incorporates proprietary circuit techniques that eliminate the use of reactive phase shifters and filters while maintaining accuracy, stability, and greater than 40 db harmonic rejection. In addition to phase angle; total, fundamental, in-phase and quadrature voltages can be measured with respect to an arbitrary phase-shifted reference. The reference can vary from 150mV to 150V without the need for calibration or adjustment. The 321's versatility, accuracy, and ease of use make it ideally suited for both laboratory and production line use.

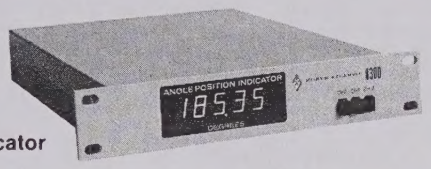
ANGLE POSITION INDICATORS

Model 800
Synchro Panel Meter

The new Model 800 Synchro Panel Meter reaches a new level in the price/performance balance of synchro angle indicators. Designed for system or test set applications, the Model 800 features 0.1° resolution and operates directly off the stator and rotor signals, requiring no separate power. With its type II tracking loop, the Synchro Panel Meter has full digital output and is available with 0 to 359.9, ± 179.9 and a fully variable range. It has ± 2° offset adjust to allow for final system zeroing without the sometimes difficult task of physically "tweaking in" a remote synchro. Pin programming for all standard synchro or resolver signals offers maximum user flexibility.

With option 9999, the Model 800 can be user programmed, via internal DIP switches or open collector logic, for 0 to any positive four digit full scale value desired. This user programming allows a common device to be used in different systems requiring various full scale values (i.e., batch weighing, rod position, level control, etc.).

ANGLE POSITION INDICATORS

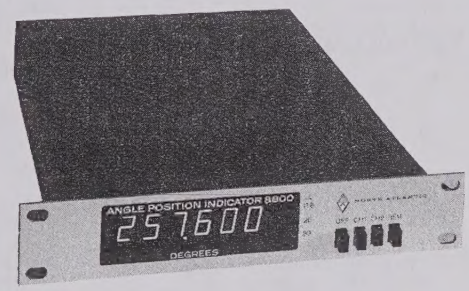


Model 8300
Angle Position Indicator

The Model 8300 offers a combination of LSI-enhanced reliability, low cost, and features never before available in any angle position indicator. The unit can be programmed for line-line, synchro/resolver mode via direct hard wire connection at the rear mating connector. Each of the two data channels may have independent references from 47Hz to 440Hz. Thus, one channel may read 11.8V, 400Hz resolver data and the other 90V, 60Hz synchro data. Absolute accuracy is .05° for data rates up to 5rps (1800°/second). Resolution is .01°. Digital outputs are 5-decade BCD data lines plus converter control and data status lines. Options include degrees/minutes display, +180° display, and higher accuracy (+0.03°).

Model 8310
Angle Position Indicator

The model 8310 is a bench top model of the 8300 featuring full front panel controls and input terminations, data freeze button, tilt stand and mounting ears for rack mounting (if desired).



Model 8800
Angle Position Indicator

The Model 8800 is a growth version of the basic model 8300 described above. Featuring a resolution of 0.001 and accuracy to 0.004°, the LSI based Model 8800 truly represents a major advance in synchro-to-digital converter technology. A full type II tracking servo, the 8800 can track synchros at speeds up to 1000°/sec. Phase sensitive detection inherently rejects unwanted harmonics and noise contained in the incoming signal. Built-in auto-phase correction further reduces the possibility of errors caused by quadrature and harmonics when reference and signal are out of phase. The 8800 accepts any standard line-to-line level *without* preselecting or preprogramming the input signal. This unique feature is due to an auto-ranging circuit that displays the applied input signal voltage level on the front panel. Two pushbutton front-panel selectable input channels are provided. BCD outputs, data freeze and converter busy signals make the unit ideal for ATE application. The display is a bright, easy-to-read, 0.55" gas discharge planar display coupled with our exclusive LAZY-EIGHT ambiguity indicator (discerns between real 8's and 8's due to jitter).

Model 8810
Angle Position Indicator

The Model 8810 is a bench top version of the model 8800 (above) featuring full front panel controls and input terminations, tilt stand and ears for rack mounting (if desired). Additionally, the Model 8810 is available with the 488 IB (IEEE STD 488-1975) interface bus for ATE applications.

PROGRAMMABLE RESOLVER/SYNCHRO SIMULATORS

Model 5310
Programmable Resolver/Synchro Simulator

The Model 5310 can be used as a bench-top Resolver/Synchro Simulator or as a completely programmable device for ATE systems.

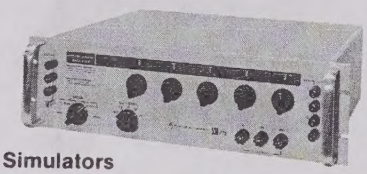
The unit features fully isolated inputs and outputs and is protected against accidental short circuits and overloads on the output and over-voltage and transients on the power line input.

Standard features include full remote programmability for line-to-line level, reference levels, synchro or resolver mode and output angle.

Remote control is parallel BCD or binary bussable tri-state; IEEE-488-1978 GPIB is available. The 5310 also has full front-panel controls for manual operation.

Featuring 18 bit resolution, 3.0VA output and 36 arc second accuracy, the 5310 is ideally suited for many commercial and military applications.

RESOLVER/SYNCHRO SIMULATORS & BRIDGES

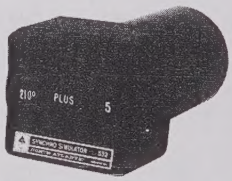


Series 530
Resolver/Synchro Simulators

These simulators provide the ideal outputs for driving resolvers and synchros at 11.8, 26, 90 and 115V line-line voltages. These line-line voltages are all available with either 26V or 115V 400Hz excitation, and feature isolated input and output. Accuracy is 2 arc-seconds. Resolution is .0001°, with standard units 3½" full rack panel.

Model 530/20
Broadband Resolver/Synchro Simulator

The Model 530/20 features 10 arc-second accuracy at 60Hz, 400Hz, and 800Hz, and 20 arc-second accuracy at 10KHz. It is useable over the entire frequency band from 50Hz to 10KHz. This broadband frequency characteristic makes it an ideal instrument for test facilities desiring the maximum capability in each instrument.



Model 532
Low-Cost Synchro Simulator

Model 532 is a miniature synchro simulator offering precision performance in a small panel-mounted unit suitable for production test, ground support and similar systems. Direct simulation of 11.8V 400Hz line-line synchro transmitters (CX) is provided, with dial reading in 30° segments plus 5° increments selectable by sealed thumbwheel switches and accurate to 30 arc-seconds.

Model 540/10
Resolver/Synchro Bridge

These bridges permit direct measurement of resolver and synchro transmitters. They feature a constant null gradient output voltage, isolated input and output, and input impedance over 500K. The Model 540/10 features 2 arc-second accuracy at 400Hz.

Model 540/20
Broadband Resolver/Synchro Bridge

The Model 540/20 features 10 arc-second accuracy over most of the frequency band from 55Hz to 10KHz. Also featured is a constant null gradient voltage which permits deviation measurements by using a Phase Angle Voltmeter as the null detector.

TECHNICAL BULLETINS

North Atlantic publishes a series of technical bulletins dealing with theoretical design and application aspects of instrumentation. Copies are available without charge from our Sales Department or from any North Atlantic Sales Engineering Representative.

NO. 112 CONVERTING MOTION TO DIGITAL DATA
NO. 113 SERVO-STYLE CIRCUIT SPEEDS SYNCHRO-TO-DIGITAL CONVERSION
NO. 117 SYNCHRO/RESOLVER-TO-DIGITAL CONVERSION FOR COMPUTER INTERFACE
NO. 120 PHASE ANGLE VOLTMETERS.
NO. 121 ANGLE-SENSING TRANSDUCERS FOR SHAFT-TO-DIGITAL CONVERSION

SALES OFFICES

North Atlantic Sales Engineering Representatives are located in principal cities throughout the world. These representatives are available for consultation, can provide engineering data on any of the North Atlantic products, or prepare technical and cost proposals for special requirements on computer interface equipment, phase sensitive instrumentation, resolver/synchro instrumentation and automatic test equipment. To locate the Sales Engineering Representative serving your area, please consult the current editions of EEM (Electronic Engineers Master), or contact our Sales Department.

SERVICE CENTERS

Factory service is available at authorized Service Centers in:

LOS ANGELES, CA
MINNEAPOLIS, MN
HAUPPAUGE, NY
LONDON, ENGLAND
MUNICH, GERMANY
PARIS, FRANCE
TEL AVIV, ISRAEL
TOKYO, JAPAN

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Hauppauge, NY 11788
(516) 582-6500
(800) 645-5292
TWX 510-227-9660
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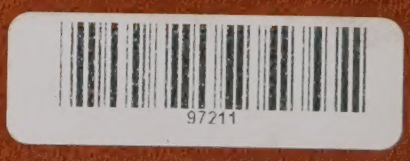
97211